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Enisse Kharroubi

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Illiquidity, Financial Development and the Growth-Volatility Relationship.

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Résumé.

Ce papier étudie comment le développement financier affecte la relation entre croissance moyenne et volatilité de la croissance à travers l'occurrence de crises de liquidité. Dans un premier temps, on montre dans un modèle micro-économique que la mise en oeuvre imparfaite des contrats crée un biais vers le court terme dans le financement des projets de long terme. Ceci peut mener à des situations où la maturité du passif est plus courte que celle des actifs et se transformer en crise de liquidité. Ensuite à l'aide de ce mécanisme, on montre dans un modèle macro-économique que la relation entre croissance moyenne et volatilité de la croissance est plus probablement négative dans les pays en développement et plutôt positive dans les pays développés. Finalement on montre que les prédictions du modèle sont vérifiées empiriquement.

Mots-clés : Illiquidité, maturité de la dette, croissance, volatilité, développement financier.

Classification JEL : E44, G30, O16.

Abstract.

This paper studies how financial development affects the relation between average growth and growth volatility through liquidity crises. We first establish in a micro model that imperfect enforceability creates a short term bias in contracts financing long term investments. This can generate maturity mismatches between firms assets and liabilities and lead to liquidity crises. Then with this mechanism, we show in a macro framework that the relation between average growth and growth volatility is more likely to be negative in developing countries, but more likely to be positive in developed economies. Finally we provide empirical evidence which supports the prediction of the model.

Keywords: Illiquidity, debt maturity, growth, volatility, financial development.

JEL Classification: E44, G30, O16.

Résumé non technique.

L'objet de cet article consiste à étudier comment le développement financier peut modifier la relation entre croissance moyenne et volatilité de la croissance à travers l'occurrence de crises de liquidité. Pour ce faire l'article commence par étudier les déterminants de la maturité des contrats de financements des entreprises lorsque la mise en œuvre des contrats est imparfaite et que la technologie des entreprises est illiquide. Dans ces conditions, les prêteurs imposent un biais vers la dette de court terme dans les portefeuilles de financement des entreprises. En effet, avec un contrat de long terme, il existe au moins une date entre le moment où le contrat est signé et le moment où il doit être honoré. Or à cette date, les entreprises peuvent décider de fuir leurs responsabilités en détruisant leur projet initial : cela réduit la rentabilité du capital mais le défaut sur la dette de long terme devient alors profitable. Pour prévenir cette possibilité, les prêteurs peuvent accroître la part de la dette de court terme dans les portefeuilles de financement des entreprises. Ils disposent alors d'un pouvoir de contrôle effectif car ils peuvent à présent sanctionner une entreprise qui fuit ses responsabilités en réclamant le paiement des dettes de court terme.

Cependant, bien que ce mécanisme résolve un problème d'incitation micro-économique, il peut générer un problème macro-économique de coordination entre les prêteurs. En effet, si ces derniers acceptent de proroger les dettes de court terme, les entreprises sont alors capables de mener à bien leur projet de long terme. Leur rendement final est élevé et elles n'ont alors pas d'incitations à faire défaut sur la dette de long terme ce qui incite les prêteurs à accepter de proroger les dettes de court terme. En revanche si les prêteurs refusent de proroger les dettes de court terme, les entreprises sont alors incapables de mener à bien leur projet de long terme, leur rendement final est faible et elles sont alors incitées à faire défaut sur leurs dettes de long terme. Les prêteurs refusent alors de proroger les dettes de court terme puisqu'autrement les dettes prorogées ne seraient jamais honorées. Cela montre que la résolution du problème d'incitation micro-économique peut se faire au détriment de l'efficacité macro-économique : le biais vers le court terme des portefeuilles de financement peut donner naissance à un équilibre dominé où les entreprises sont contraintes de détruire leurs projets de long terme en raison d'une panique qui poussent les prêteurs à demander le paiement de la dette

de court terme.

Finalement pour obtenir les résultats recherchés quant à la relation entre croissance moyenne et volatilité de la croissance, on se focalise sur le ratio entre le stock de capital des prêteurs et celui des entreprises. Ce ratio a, toutes choses égales par ailleurs, deux effets principaux. Il a d'abord une influence négative sur l'efficacité de l'économie puisque les entreprises ont par définition accès aux technologies les plus productives. Ainsi une hausse de ce ratio réduit généralement la croissance moyenne de l'économie. Ensuite, le ratio entre le stock de capital des prêteurs et celui des entreprises a une influence positive sur le volume de capital disponible pour les prêts en général et pour le refinancement des dettes de court terme en particulier. Il y a alors deux cas : Lorsque le ratio entre le stock de capital des prêteurs et celui des entreprises est grand, une variation positive de ce ratio réduit la probabilité qu'une panique sur la dette de court terme ait lieu, ce qui réduit la volatilité de la croissance. En revanche, lorsque le ratio entre le stock de capital des prêteurs et celui des entreprises est faible, une variation positive de ce ratio accroît la proportion d'entreprises qui adoptent des stratégies de financement risquées, i.e. qui exposent au risque de panique sur la dette de court terme, ce qui accroît in fine la volatilité de la croissance.

En identifiant ce dernier cas – le ratio entre le stock de capital des prêteurs et celui des entreprises est faible – à celui des pays en développement et le cas précédent – le ratio entre le stock de capital des prêteurs et celui des entreprises est élevé– à celui des pays développés, le modèle prédit ainsi que la croissance moyenne est corrélée positivement (resp. négativement) à la volatilité de la croissance dans les pays développées (resp. dans les pays en développement). Sur la base d'estimations économétriques, l'article montre finalement qu'il existe des éléments empiriques permettant de valider ces résultats théoriques.

Non technical summary.

In this paper, we study how financial development affects the relation between average growth and growth volatility through liquidity crises. To do so we first study the optimal maturity of firms' liabilities when their technology is illiquid and financial contracts are imperfectly enforceable. To circumvent these two issues, we show that lenders impose on firm debt portfolios a bias towards short term debt. For lenders, the problem with a long term debt contract lies in the freedom it leaves to the borrower. In a long term debt contract, there is at least one date between the contracting date and the payment date and the borrower can choose to shirk at that interim date, i.e. stop his project interim, re-invest his capital in a less efficient technology to eventually default on long term loans. To prevent borrowers from doing so, lenders can increase the share of short term debt in firm debt portfolios. They then have an effective controlling power because if a firm stops its project interim, lenders can sanction it by asking for short term debt repayments.

Secondly however, we show that while this mechanism solves a micro incentive problem, it can generate a global coordination issue between lenders: if lenders accept to roll-over short term debts, firms are then able to carry out their long term projects; the final return of their investment is then large. Hence they have no incentive to default on long term loans and lenders are then ready to roll-over short term debts. On the contrary, if lenders refuse short term debts roll-over, firms are then unable to carry out their long term projects; the final return of their investment is low. Hence they have incentives to default on long term loans and this prompts lenders to refuse short term debts roll-over since otherwise they would undergo a default on the rolled-over debts. This shows that the resolution of the micro incentive problem does come in fact at the expense of macroeconomic efficiency: the bias on short term debt can give rise to a dominated equilibrium where firms are compelled to stop their projects due to a panic on short term debts.

Finally to derive our macroeconomic results, we focus on the ratio between lenders and entrepreneurs (firms) capital stock. A positive change in this ratio has, every thing else equal, two main effects. First it reduces the efficiency of the economy because by definition entrepreneurs have access to the most efficient technologies. Therefore a positive change in the ratio between lenders and entrepreneurs capital stock generally reduces average growth. Secondly an increase in this ratio has a positive impact on the resources available for granting loans in general and for short term debt interim re-financing in particular. Then there are two cases: when the ratio between lenders and entrepreneurs capital stock is large, a positive change in this ratio reduces the probability that a run on short term debt happens which reduces growth volatility. On the contrary, when the ratio between lenders and entrepreneurs capital stock is low, a positive change in this ratio increases the share of entrepreneurs who adopt risky financing strategies - strategies making entrepreneurs vulnerable to a panic on short term debts - which increases growth volatility.

Identifying the case of a low (resp. large) ratio between lenders and entrepreneurs capital stock to a developing (resp. developed) economy, our model predicts that average growth and growth volatility are negatively (resp. positively) related in developing (resp. developed) economies. We finally show that empirical evidence seems to confirm this result.

1. Introduction.

Following the last financial crises, many voices rose to explain that these crises were new compared to previous ones (Radelet and Sachs [1998] and Corsetti, Pesenti and Roubini [1999]). Indeed the usual features known to trigger crises (governments unsustainable economic policies (Krugman [1979])) were absent or could not by themselves imply so severe crises (Baig and Goldfajn [2002]). Instead, a number of new phenomena arose such as the large levels of short term debt firms had accumulated in the pre-crisis period.

	Pakistan	Thailand	Korea	Malaysia	Hong Kong	Philippines	China	Taiwan	U.S.A.
DE. ratio	0,999	0,915	2,485	0,114	0,42	0,239	0,553	0,195	0,16
C. ratio	0,993	1,143	1,078	1,296	1,352	1,37	1,321	1,587	2,097
Q. ratio	0,51	0,697	0,773	0,913	0,947	0,961	0,968	1,037	1,385

Table 1: Aggregate financial indicators (median) for non financial firms[1].

Several explanations have then been brought to explain this build-up in corporate imbalances. Two of them have particularly emerged. According to the first one, "crony capitalism" can explain the last figures (Krugman [1998]) because it has played a major role in encouraging firms to take inefficient decisions (over investment, excessive risks, etc...), in distorting individual incentives. The implicit insurance arising from "crony capitalism" prompted agents to believe that they could benefit from short term debt low cost while the government would help them overcome potential illiquidity problems. The second explanation refers to the "Original Sin" hypothesis (Eichengreen and Haussman [1999]). According to it, agents financial positions such as those described in table 1 are due to firms inability to choose their financial portfolios: Firms have no available financial strategy but the risky ones. Although they know ex ante the risks associated with this type of financial instruments, they are somewhat constrained to adopt these "dangerous" financing strategies because this is the only way to get capital from financial markets.

[1] Source : Claessens, Djankov et Nenova [2000]. DE ratio refers to the debt equity ratio computed as the ratio of total debt to the market value of the firm. C. ratio refers to the current ratio computed as the ratio between current assets and current liabilities, i.e. assets and liabilities with a below one year maturity. Q. ratio refers to the quick ratio computed as of current assets less inventories to current liabilities. Data are for 1995-1996.

Although both of these explanations may be reasonable and explain the vulnerability of countries to financial crashes, they are incomplete and fairly ad-hoc in their foundations. In the crony capitalism explanation, the implicit insurance scheme or the collusion links between firms managers and politicians are exogenous. There is no positive theory of crony capitalism. As to the "Original Sin", we need to explain why it can be relevant for developing economies while it does not seem to be for developed countries. For instance, the share of short term debt in corporate debt portfolios decreases with economic and financial development (Demirgüç-Kunt and Maksimovic [1999]).

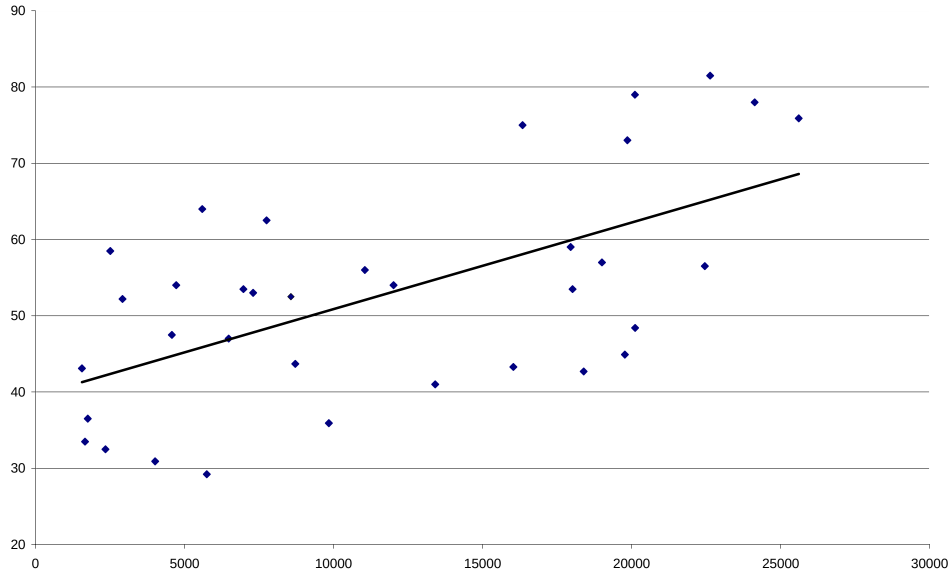

Figure 1 : PPP income per capita vs. proportion of long term debt[2].

We need to understand how economic and financial development modifies financial contracts to understand the nature of the "Original Sin" problem. In this paper, our aim is twofold. First we try to use an explicit framework which can help explain why private agents do use risky financial strategies. Second we aim at exploring the macroeconomic consequences of private financial strategies on growth and volatility.

[2]Source : Claessens, Djankov and Lang [1998] and Penn World Tables 6.1. Each point represents a country. The income per capita in 1988 in PPP is on the x-axis and the median proportion of long term debt for non financial firms for 1988-1996 is on the y-axis.

1.1. The mechanism of the model.

To answer these questions, we study how the maturity of firms debts is determined. The mechanism is the following. When contracts are imperfectly enforceable, lenders impose on the debt portfolio of borrowers investing in long term activities a bias towards short term debt. For lenders, the problem with long term debt lies in the freedom it leaves to the borrower. In a long term debt contract, there is at least one date between the contracting date and the payment date and the borrower can choose to shirk at that interim date. In the model, the borrower can decide to stop his project interim, re-invest his capital in a less efficient technology to eventually default on long term loans. To prevent borrowers from doing so, lenders can increase the share of short term debt in borrowers debt portfolios[3]. They then have an effective controlling power because if the borrower stops his project interim, lenders can sanction him by asking for short term debt repayments[4].

However although this mechanism solves a micro incentive problem, it generates a global coordination issue when borrowers rely heavily on short term debt because if lenders accept (resp. refuse) to roll over short term debts, borrowers are then able (resp. unable) to carry out their long term projects, their final return is large (resp. low) and they do not have (resp. do have) incentives to default on long term loans. It is then rational for lenders to accept (resp. refuse) short term debts roll-over. Therefore both the situations where lenders accept and refuse to roll-over short term debts are equilibria and borrowers can be forced to stop their projects because lenders are unable to coordinate to avoid inefficient runs on short term debts[5].

To derive our macroeconomic results, we focus on the ratio of lenders to borrowers wealth. A positive change in this ratio has, every thing else equal, two main effects. First it reduces the efficiency of the economy because by definition borrowers have access to the most efficient technologies. A positive change in the lenders to borrowers wealth ratio therefore generally reduces average growth. Secondly this ratio has a positive impact on the available resources for short term debt re-financing. Then, when it is low, a positive change in the lenders to borrowers wealth ratio prompts entrepreneurs to adopt more frequently risky financing strategies which increases growth volatility. On the contrary, when it is large, a positive

[3] Here we implicitly assume that borrowers face an infinitely elastic capital supply so that quantities and not prices (interest rates here) adjust to verify incentives constraints.

[4] Here we implicitly assume that lenders can observe a borrower who stops his project.

[5] The crises that appear in the model are therefore ex ante efficient but ex post inefficient.

change in the lenders to borrowers wealth ratio reduces the probability that a run would happen which reduces growth volatility. Identifying the case of a low (resp. large) lenders to borrowers wealth ratio to a developing (resp. developed) economy[6], the model predicts that average growth and growth volatility are negatively (resp. positively) related in developing (resp. developed) economies. Finally we provide empirical evidence which seems to confirm this result.

1.2. Related literature.

Four types of literature are related to the issues studied in this paper. First, liquidity issues have been studied in the seminal Diamond-Dybvig [1983] paper. Since panics can happen in the banking sector due to the fact that liabilities are short term and assets long term, banks can act as pools of liquidity to stop these panics. Diamond [1991] is closer because it shows how firms financial choices may help reducing informational asymmetries with their lenders. In Diamond [1991], firms with good prospects are more likely to issue short term debt because their probability of being confronted to liquidity shocks is smaller. Flannery [1986] and Kale and Noe [1990] also consider financial choices as signals on the quality of the projects financed. The approach in our paper is however different because firm heterogeneity does not play any role. It is the nature of long term projects (the possibility to stop them interim) which prompts firms to borrow short term. Rajan [1992] introduces ex ante moral hazard and the choice between banking and market finance to show that both short and long term contracts have advantages and drawbacks. Finally Rey and Stiglitz [1993] is the closest paper since it shows that short term contracts give lenders a monitoring power on borrowers. Our argument is close. However we first stress the disciplining effect of short term debt rather than its monitoring power. Second we show that the disciplining effect of short term debt is not cost free since it may come with multiple equilibria and inefficient project terminations due to runs on firms short term liabilities.

Secondly this paper is close to the literature which tries to explain micro or macro stylized facts based on corporate financial contracts. Albuquerque and Hopenhayn [2004] study how optimal maturity debt

[6]Following data from Beck, Demirgüç-Kunt and Levine [1999], there exists a positive correlation between the development level (income per capita) and the amount of financial intermediaries assets to GDP which is a proxy for the ratio of lenders to borrowers wealth. cf. figure 6 in appendix.

contracts help explain the dynamics of firms development. Rodrik and Velasco [1999] try to explain why developing countries can rationally accumulate unsustainable amounts of short term debt, the idea being that with illiquid projects, accumulating short term debt increases the price of long term debt because the premium on long term debt depends positively on the amount of short term debt.

Thirdly this paper is related to the literature dealing with the macroeconomic impact of capital market imperfections (Bernanke and Gertler [1989], Greenwood and Jovanovic [1990], Acemoglu and Zilibotti [1997], Kiyotaki and Moore [1997] or Aghion Banerjee and Piketty [1999]) which points out the fact that capital market imperfections can generate or exacerbate fluctuations.

Finally this paper is related to the literature on growth and volatility. While the common wisdom, influenced by Ramey and Ramey [1995], points out a negative relationship, some arguments supporting a positive relationship have been developed (Jones, Manuelli and Sachetti [1999] or Tornell, Westerman and Martinez [2004]). Here our contribution consists in saying that if growth volatility comes mainly from financial crises, then the relation with average growth is more likely to be positive in developed economies but more likely to be negative in developing economies. Recently, Aghion, Angeletos, Banerjee and Manova [2004] have come up to a similar conclusion, their mechanism being based on the interaction between financial markets imperfections and R&D activities.

1.3. Road map of the paper.

The paper is organized as follows. The microeconomics of the capital market is established in the next section. In section 3, we apply this micro framework to a macroeconomic model. We derive firms optimal choices in section 4. In section 5, we build the equilibrium and establish the main results as to growth and volatility. Conclusions are drawn in section 6.

2. A two period model of the credit market.

2.1. A capital market with ex post moral hazard.

When contracts are imperfectly enforceable, a relation between the severity of borrowing constraints and the composition (between short term and long term loans) of the debt portfolio can be drawn. To illustrate it, let us consider:

H1: A risk neutral borrower-entrepreneur with initial wealth W at time t who lives two periods and maximizes his end-of-life consumption.

H2a: At date t, the entrepreneur can invest in a technology whose production function writes as $y_{t+2} = Rk_t^*$ where $k_t^* = \min\{k_t, k_{t+1}\}$ and k_t is the capital stock[7] invested in the project at date t.

H3: He is granted at date t a loan L from a pool of risk neutral investors, made a short term loan αL (which must be repaid at date $t+1$) and a long term loan $(1-\alpha)L$ (which must be repaid at date $t+2$). The gross risk free interest rate on short (resp. long) term debts[8] is r_s (resp. r_l).

H4: Short term contracts are perfectly enforceable but long term contracts are imperfectly enforceable[9], borrowers can default strategically on long term contracts at a marginal cost τ.

A borrower pays for his long term debts if and only if this makes him better-off. The incentive compatibility constraint writes as

$$R(W + L - \alpha r_s L) - (1-\alpha) r_l L \geq (1-\tau) R(W + L - \alpha r_s L)$$

We then have the following proposition.

[7] The production function implies that the entrepreneur can extract capital from his project at date $t+1$ (before output realizes) at the cost of reducing final output.

[8] The interest rates r_s and r_l are exogenous and such that investors are indifferent between lending on a short maturity or on a long one. As a result we assume that no investor makes exclusively short or long term loans. All investors have both of them.

[9] The difference in enforceability between short and long term contracts is only made for convenience, to simplify the exposition of the model. Assuming that both short and long term financial contracts are imperfectly enforceable would not change neither the mechanism nor the results of the model although the incentive compatibility constraints would be more complicated.

Proposition 1. *Under assumptions H1, H2a, H3, H4, assuming $r_l > \tau R$ and $r_s > 1$ and noting $\mu = \frac{L}{W}$ the debt equity ratio and α the proportion of short term debt, incentive compatible debt portfolios (α, μ) verify*

$$\mu \leq \overline{\mu} \equiv \frac{\tau R}{(1-\alpha)\, r_l + \alpha \tau R r_s - \tau R} \tag{2.1}$$

Proof. Elementary algebra on the last incentive compatibility constraint yields the proposition. ■

The right hand side expression of (2.1) is an increasing function of α when $r_l > \tau R r_s$, i.e. if τ is sufficiently small. We consider this case in the following[10].

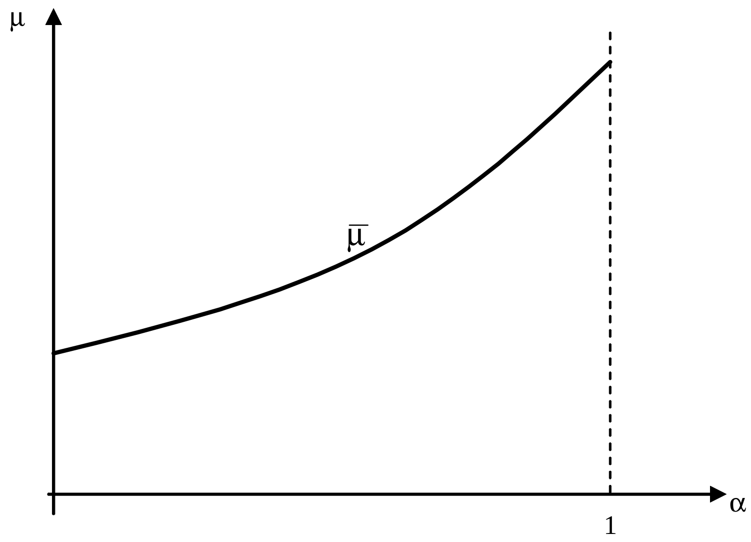

Figure 2: Credit constraints and debt portfolio composition under long term imperfect enforceability.

2.2. A capital market with interim and ex post moral hazard.

We introduce interim moral hazard as the possibility for a borrower-entrepreneur to stop his project interim, i.e. at date $t+1$ before reaping the final return R, to reinvest in a project, yet less productive but also easier to default on. An entrepreneur can claim ex ante to be willing to carry out his project till maturity. But effectively he stops it interim and defaults on long term loans.

[10] The condition $r_l > \tau R r_s$ is a necessary condition to generate a trade-off between the quantity of capital an entrepreneur can borrow and the maturity mismatch he accepts between his assets and his liabilities. The case $r_l \leq \tau R r_s$ is therefore uninteresting because trivial.

2.2.1. Incentives and contracts.

Let us consider the borrower-entrepreneur of the previous paragraph and add the following assumptions:

H2b: At date t, the entrepreneur can invest in a technology whose production function[11] writes as $y_{t+2} = \widetilde{R}k_t^*$ with $\widetilde{R} = r + (R - r)\,\mathbf{1}\left[k_t^* \geq (1-\eta)\,k_t\right]$ where $\mathbf{1}[x]$ is equal to 1 if x is true and 0 otherwise, $0 < \eta < 1$ and $R > r$.

H5: The marginal cost of default for the entrepreneur on long term loans is τ if $\widetilde{R} = R$ and τ' if $\widetilde{R} = r$. There is moral hazard[12] at date $t+1$: $R > r$ and $(1-\tau')\,r > (1-\tau)\,R$.

If an entrepreneur could commit to stick to the large return $\widetilde{R} = R$, then the incentive compatible contract (α, μ) would verify the following conditions

$$\mu \leq \overline{\mu} = \frac{\tau R}{(1-\alpha)r_l + \alpha\tau R r_s - \tau R}$$

$$\alpha\mu r_s \leq \eta\,(1+\mu)$$

On the contrary, if the entrepreneur wants to get the low return $\widetilde{R} = r$, to default eventually on long term loans, then the incentive compatible contract (α, μ) must verify the following condition

$$\mu \leq \underline{\mu} \equiv \frac{\tau' r}{(1-\alpha)\,r_l + \alpha\tau' r r_s - \tau' r}$$

As is clear if the assumptions $R > r$ and $(1-\tau')\,r > (1-\tau)\,R$ are true then $\overline{\mu} > \underline{\mu}$. An entrepreneur who is offered a contract $\overline{\mu}$ and who stops his project to get the low return $\widetilde{R} = r$, therefore defaults on all his long term debts. We need to determine the incentive compatible contracts in this new environment. The next proposition does so.

Proposition 2. *Under assumptions H1, H2b, H3-H5, and noting $\sigma = R - (1-\tau')\,r$, an entrepreneur who*

[11] This technology is therefore illiquid: an entrepreneur who extracts capital at date $t+1$ not only affects the size of his project. He also affects the marginal return of his project. The entrepreneur must therefore be sufficiently patient to obtain a large return.

[12] The existence of interim moral hazard for a illiquid project is natural because the cost to default is much lower once the entrepreneur has liquidated his investments and reinvested his capital in a short term technology. Illiquidity is therefore viewed as a particular case of interim moral hazard.

is served a contract (α, μ) *pays for his debts if and only if* $\mu \leq \underline{\mu}$ *or*

$$\left.\begin{array}{l} \mu \leq \widehat{\mu} \equiv \frac{\sigma}{(1-\alpha)r_l+\alpha\sigma r_s-\sigma} \\ \alpha\mu r_s \leq \eta\left(1+\mu\right) \end{array}\right. \quad \textit{if } \mu > \underline{\mu} \tag{2.2}$$

Proof. cf. appendix.

Two remarks can be made. First, under the interim moral hazard assumption, $\overline{\mu}$ does not belong to the set of incentive compatible contracts since $\overline{\mu} > \widehat{\mu}$. The introduction of interim moral hazard therefore reduces the borrowing capacity of entrepreneurs. Secondly, since $r_l > \tau R r_s$, under the interim moral hazard assumptions we have $r_l - \sigma r_s > 0$. This implies that an entrepreneur who invests in the production technology with a given level of debt μ will have to bear a higher proportion of short term debt w.r.t. a situation without interim moral hazard. Interim moral hazard introduces a "bias" towards short term debt because short term debt appears as a disciplining device for lenders. They impose this bias to make sure that borrowers do not take advantage of the presence of interim moral hazard.

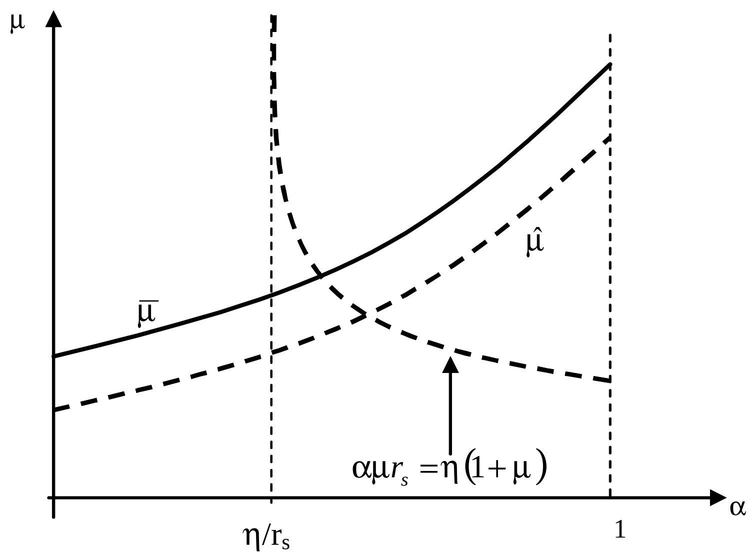

Figure 3: Credit constraints and debt portfolio composition under imperfect enforceability, illiquidity and interim moral hazard.

2.2.2. Short term debts roll-over.

Let us finally consider the borrower-entrepreneur of the previous paragraph and add a final assumption:

H6: Lenders can observe entrepreneurs decision interim (to proceed or not at date $t+1$) **and then** decide on that basis how to behave as to short term debt repayment.

In the previous paragraph we have shown that the introduction of interim moral hazard generates a "bias" towards short term debt. Since lenders impose that bias to prevent borrowers from stopping their projects, they can also withdraw it when interim moral hazard disappears, i.e. after they observe that borrowers have not stopped their projects. In this case, lenders accept to transform short term debts into long term ones. If an entrepreneur decides to proceed with his project with a large return then it is incentive compatible for lenders to reduce the proportion of short term debt whereas if an entrepreneur decides to stop his project then lenders have to ask for full short term debt repayments. The following proposition then gives the conditions on how short term debt roll-over is realized:

Proposition 3. *Under assumptions H1, H2b, H3-H6, if an entrepreneur with a debt portfolio* (α, μ) *proceeds with his project, then it is incentive compatible for lenders to exchange at date* $t+1$ *the debt portfolio* (α, μ) *contracted at date* t *against a debt portfolio* (β, μ) *if and only if*

$$\beta \geq \frac{1}{r_{l,s} - \tau R r_s} \left[\alpha r_{l,s} + (1-\alpha) r_l - \tau R \frac{1+\mu}{\mu} \right]^+ \tag{2.3}$$

where $[y]^+ = \max\{y; 0\}$ *and* $r_{l,s}$ *is the gross interest rate on rolled-over short term debts.*

Proof. cf. appendix.

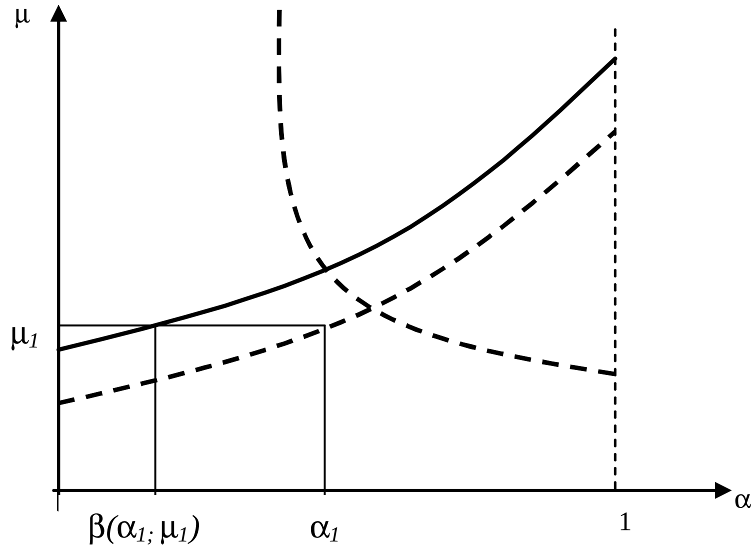

Figure 4: Debt portfolio and short term debt roll-over.

We have therefore established three results in this section. First borrowers can increase their borrowing capacity when they accept debt portfolios with a shorter maturity. Second, lenders bias debt portfolios towards short-term debt when borrowers can deviate from the project they invest in initially. Finally short term debt roll-over is possible if lenders can observe borrowers' decisions to proceed or to deviate before short term debt repayments happen. Let us now introduce this capital market framework in a macroeconomic model in order to shed some light on the aggregate consequences of the structure of financial contracts. In particular we determine how borrowers financial strategies impact aggregate growth and volatility.

3. Hypotheses and description of the model.

3.1. Agents and technologies.

We consider a single good economy with two types of risk neutral agents, entrepreneurs and workers. There is a continuum of unit mass of each type of agent. All agents live for two periods and generations are non overlapping. The utility of an agent is $u = b^{\gamma}c^{1-\gamma}$ where c (resp. b) is the end-of-life consumption (resp. bequest) of an agent and γ is a parameter ($0 < \gamma < 1$).

At the beginning of their lives, entrepreneurs have access to the production technology: $y_{t+2} = \widetilde{R}k_t^*$ with

$k_t^* \equiv \min\{k_t, k_{t+1}\}$ and $\widetilde{R} = r + (R-r)\,\mathbf{1}\,[k_t^* \geq (1-\eta)\,k_t]$ with $R > r$ and $\mathbf{1}\,[x]$ is equal to 1 if x is true and 0 otherwise. At any time, workers have access to a storage technology[13]: $y_{t+1} = rk_t$ with $r > 1$. Moreover at the beginning of their lives, workers have a labor supply l which we normalize to one. They can invest it in a labor technology whose production function writes as $y_{t+2} = w_t l_t$. This is a standard constant returns to scale technology with one difference: $w_t = wk_t$ where k_t is the aggregate capital stock invested in the production technology at date t by entrepreneurs[14].

The capital market of this economy is similar to the previous section[15]. Entrepreneurs' technology is more capital efficient than that of workers: $R > r^2$. Therefore entrepreneurs can borrow capital from workers. There are two types of financial contracts, a short (one period) and a long term (two periods) debt contract. Long term contracts are imperfectly enforceable (borrowers can default strategically). An entrepreneur who defaults on his long term contracts has to pay a cost on final output (τ when $\widetilde{R} = R$, and τ' when $\widetilde{R} = r$). The production technology is subject to *interim* moral hazard: $(1-\tau)\,R < (1-\tau')\,r$. Finally agents types, financial choices and wealths are all observable.

3.2. Timing of the model.

At the beginning date (date t), entrepreneurs invest in the production technology and make financial (short or long term debt) choices. Workers make loans to entrepreneurs, they invest in the storage technology the capital they have not lent and they invest their labor supply in their labor technology. At the *interim* date (date $t+1$), short term debts are partially or fully rolled-over, illiquid projects may be stopped. At the final date (date $t+2$), the returns on the different projects are realized according to what happened at the interim date. Long term and rolled-over short term debts are paid back, agents consume part of their end-of-life wealth and bequeath the other part to their off-springs who then go on on the same scheme.

[13] The assumption $r > 1$ makes sure that an agent who invests on two successive periods in the storage technology generates more output than an agent who invests on only one period.

[14] This externality makes sure that the economy does not have a degenerate steady state in which the ratio of workers to entrepreneurs wealth is equal to zero. See appendix 7.7 for details on the dynamics of the economy.

[15] In particular, assumptions H2b, H3-H6 are valid.

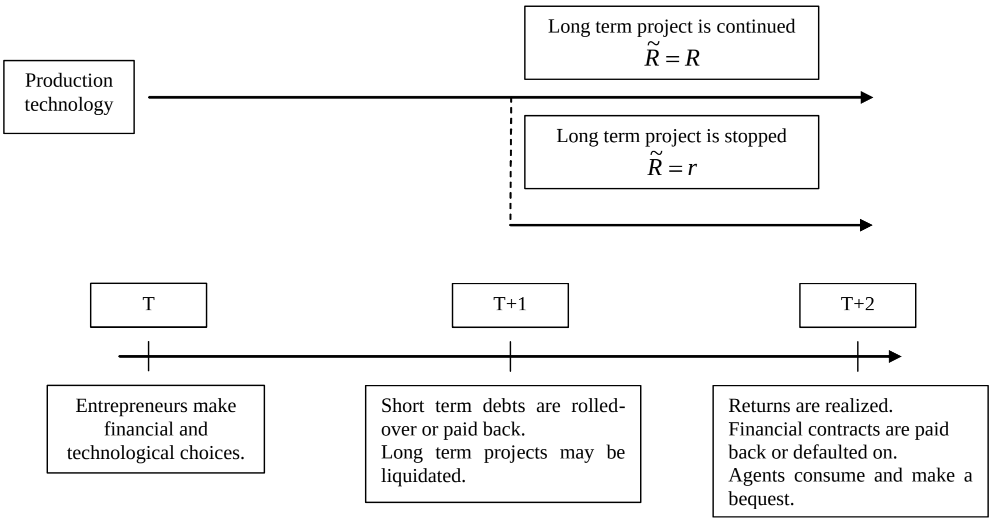

Figure 5: Timing of the model.

4. The two periods model.

4.1. Optimal debt portfolios without interim moral hazard.

If there were no interim moral hazard[16], then the expected profit of an entrepreneur with initial capital 1 would write as

$$\pi_{t+2} = (1 + \mu - \alpha\mu r_s)\, R - (1 - \alpha)\, \mu r_l$$

and his program would consist in

$$\max_{\alpha,\mu} \mu . \left[R - r_l - \alpha\left(r_s R - r_l\right)\right] \tag{4.1}$$

$$\text{s.t.} \begin{cases} \alpha\mu r_s \leq \eta\,(1+\mu) \\ \mu \leq \overline{\mu} \end{cases}$$

The first condition $\alpha\mu r_s \leq \eta\,(1+\mu)$ makes sure that short term debt repayments are compatible with entrepreneurs proceeding with their illiquid projects. The second condition $\mu \leq \overline{\mu}$ makes sure that entrepreneurs pay for their long term contracts. We can then write down the following proposition.

[16] Here we remove, and only for this paragraph, the sole assumption that $(1-\tau)\, R < (1-\tau')\, r$.

Proposition 1. *When there is no interim moral hazard, entrepreneurs choose assets and liabilities with identical maturities.*

Proof. With simple algebra, it can be shown that (4.1) is a always a decreasing function of α. Therefore entrepreneurs choose the largest amount of capital they can borrow that is compatible with exclusively long term liabilities. The optimal debt portfolio therefore does not contain short term debts, the optimal debt equity ratio is $\mu_{fb} = \frac{\tau R}{r_l - \tau R}$ and expected profits are $\pi_{fb} = (1-\tau)\frac{R r_l}{r_l - \tau R}$. ■

4.2. Optimal debt portfolios with interim moral hazard.

Let us consider an entrepreneur whose initial wealth in normalized to one, who invests in the production technology with a debt portfolio whose size is μ and contains $\alpha\mu$ short term debts. Given the results of section 2, such an entrepreneur can be confronted to two different situations. Lenders can ask him to pay for $\beta\mu r_s$ or $\alpha\mu r_s$ as short term debt repayments[17] with $\beta \leq \alpha$.

4.2.1. The safe financing strategy.

When lenders ask the entrepreneur to pay for $\alpha\mu r_s$ the entrepreneur is still able to carry out his project with a large return if and only if $\alpha\mu r_s \leq \eta(1+\mu)$. Then it is incentive compatible for lenders to ask only for $\beta\mu r_s$ as short term debt repayments since the entrepreneur is always able to continue his long term project and has no incentive to deviate. The expected profit of that entrepreneur[18] then writes as

$$\pi_{t+2} = (1 + \mu - \beta\mu r_s) R - (1-\beta)\mu r_l$$

[17] What is called here β is the minimal value verifying (2.3).

[18] The expression of expected profit π_{t+2} is valid under the assumption that the market for short term debt roll-over is perfectly competitive. This will be the case through out the paper. This assumption implies in particular that the interest rate on rolled-over short term debt is identical to the interest rate on long term debt and that β is the minimal value which verifies (2.3).

and his program consists in

$$P_1 : \quad \begin{array}{l} \max\limits_{\mu;\alpha} \mu . \left[R - r_l - \beta . \left(R r_s - r_l \right) \right] \\ \text{s.t.} \begin{cases} \alpha \mu r_s \leq \eta \left(1 + \mu \right) \\ \mu \leq \widehat{\mu} \end{cases} \end{array}$$

The solution to this problem $(\alpha_1; \mu_1)$ is reached for $\mu_1 = \mu_{fb}$ and $\alpha_1 = \frac{\tau R - \sigma}{r_l - \sigma r_s} \frac{r_l}{\tau R}$. However (α_1, μ_1) must be such that $\alpha_1 \mu_1 r_s \leq \eta (1 + \mu_1)$. Therefore this optimum is possible if and only if

$$\eta \left(\frac{r_l}{r_s} - \sigma \right) \geq \tau R - \sigma \tag{4.2}$$

This inequality means that when the production technology is not "too illiquid" then the entrepreneur is able to reach the "no interim moral hazard" optimum. Put differently, when (4.2) is verified, there is no contradiction between maximizing firms profits and supplying incentives to deter entrepreneurs from stopping their projects. Entrepreneurs expected profits π_1 are then equal to π_{fb}. As is clear, the case where (4.2) holds is uninteresting since there is no trade-off between individual incentives and firms profits. If (4.2) holds entrepreneurs are able to reach the profit level π_{fb} and the optimal debt portfolio is always $\alpha = \frac{\tau R - \sigma}{r_l - \sigma r_s} \frac{r_l}{\tau R}$ and $\mu = \mu_{fb}$. Therefore in what follows we suppose that (4.2) does not hold. In that case, the technological constraint $\alpha_1 \mu_1 r_s \leq \eta (1 + \mu_1)$ is binding and the optimal debt portfolio[19] then writes as

$$\begin{aligned} \alpha_1 &= \frac{\eta r_l}{\eta r_l + (1 - \eta) \sigma r_s} \\ \mu_1 &= \frac{(1 - \eta) \sigma + \eta \frac{r_l}{r_s}}{r_l - (1 - \eta) \sigma - \eta \frac{r_l}{r_s}} \end{aligned}$$

The entrepreneur profits[20] then write as $\pi_1 = (1 + \mu_1) R - \mu_1 r_l$.

[19] To determine α_1 and μ_1 in this case, we need to solve for the system $\mu = \widehat{\mu}$ and $\alpha \mu r_s = \eta (1 + \mu)$.

[20] On can verify that α_1 and μ_1 are such that $\min \beta (\alpha_1, \mu_1) = 0$. This means that all short term debts entrepreneurs contract are rolled-over.

4.2.2. The risky financing strategy.

When lenders ask the entrepreneur to pay for $\alpha\mu r_s$ then the entrepreneur is able to carry out his project with a large return if and only if $\alpha\mu r_s \leq \eta(1+\mu)$ while when lenders ask the entrepreneur to pay only for $\beta\mu r_s$ then the entrepreneur is able to carry out his project with a large return if and only if $\beta\mu r_s \leq \eta(1+\mu)$. Therefore when

$$\mu\beta r_s \leq (1+\mu)\eta < \alpha\mu r_s \tag{4.3}$$

there are multiple equilibria: on the one hand the roll-over decision of lenders at the interim date determines whether an entrepreneur is able or not to carry out his illiquid project till maturity while on the other hand an entrepreneur's capacity to carry out his illiquid project till maturity determines whether lenders accept to roll-over his short term contracts or not.

Let us note p the probability that lenders decide to ask for full repayment of short term debts[21]. This means that lenders ask the entrepreneur with a probability p to pay for $\alpha\mu r_s$ and with a probability $1-p$ to pay for $\beta\mu r_s$. Then the entrepreneur's expected profits[22] write as

$$\pi_{t+2} = (1-p)\left[(1+\mu-\beta\mu r_s)R - (1-\beta)\mu r_l\right] + p\left[(1+\mu-\alpha\mu r_s)r - (1-\alpha)\mu r_l\right]$$

Therefore the program of the entrepreneur writes as

$$P_2: \quad \begin{array}{l} \max\limits_{\alpha,\mu} \mu.\left[R_p - r_l - \beta(r_s R - r_l)(1-p)\right] \\ \text{s.t.} \begin{cases} \beta\mu r_s \leq (1+\mu)\eta < \alpha\mu r_s \\ \mu \leq \underline{\mu} \end{cases} \end{array}$$

where $R_p = (1-p)R + pr$. The solution then writes as $\mu_2 = \mu_{fb}$ and $\alpha_2 = \frac{r_l}{\tau R}\frac{\tau R - \tau' r}{r_l - \tau' r r_s}$. Therefore the

[21] The probaility p is now exogenous. It will be determined in the next section as an endogenous outcome of entrepreneurs individual financial choices.

[22] In this case, entrepreneurs pay for their long term debts even in the case where they are compelled to stop their illiquid project. If we considered the case in which entrepreneurs pay for their debts if and only if they are able to carry out till maturity their illiquid project then it can be easily shown that the latter situation is always dominated by the former because entrepreneurs have to pay for default costs while there are no benefits as to the optimal debt portfolio (which size is still equal to μ_{fb}) or as to interest rates (which are priced with an actuarially fair premium depending upon the repayment probability).

entrepreneur's optimal expected profits write as

$$\pi_2(p) = (1+\mu_2) R_p - \mu_2 r_l$$

Let us note strategy i the solution to program P_i. Then we have the following proposition.

Proposition 2. *When (4.2) does not hold, entrepreneurs choose strategy* 1 *if $p > q$ and strategy 2 if $p < q$ with $q = \frac{\mu_2-\mu_1}{1+\mu_2}\frac{R-r_l}{R-r}$.*

Proof. Comparing π_1 and π_2 yields the proposition. ∎

When the production technology is sufficiently illiquid, i.e. (4.2) is not verified, then entrepreneurs simply take financial decisions according to the liquidation risk they anticipate. If an entrepreneur anticipates a low roll-over probability, i.e. a high probability that a run will occur, on his short term liabilities, then he finances his investment with few short term debts to be sure not to be confronted to a run on his short term liabilities. On the contrary if the roll-over probability is high then entrepreneurs choose more short term, the composition ensuring a complete roll-over in case when lenders accept to roll-over short term claims.

We now raise the question of how sustainable the situation of asset-liability maturity mismatch can be in a macroeconomic framework. The following section tries to answer this question.

5. Equilibrium of the capital market.

5.1. Runs on short term debt.

To answer the question of whether the amount of short term debt accumulated in the economy is sustainable or not, we define what a run on short term liabilities is and how lenders coordinate to run or not.

Definition 1. *In a run on short term debt, lenders ask borrowers to pay for all short term debts whose repayment may change projects returns. The ex ante probability that a run happens is the ratio of the amount of short term debts subject to run to the amount of capital available for potential refinancing.*

This definition first implies that lenders never run on projects financed with debt portfolios (α_1, μ_1). Runs on short term debt are possible if and only if there are projects financed with portfolios (α_2, μ_2). Secondly if we note w_e entrepreneurs wealth, w_l lenders wealth, ν the proportion of entrepreneurs who play strategy 2 and $\delta = \frac{w_l}{w_e}$, then the amount of short term debts subject to run and the amount of potential refinancing respectively write as

$$\nu r_s (\alpha_2 - \beta_2) \mu_2 w_e$$

$$r [\delta - (1-\nu) \mu_1 (1-\beta_1) - \nu \mu_2 (1-\beta_2)] w_e$$

where $\beta_i = \min \beta (\alpha_i, \mu_i)$. We still have to determine ν, i.e. the type of equilibrium (pure or mixed strategy) which appears. The following proposition gives the precise conditions on the type of equilibrium which emerges.

Proposition 1. *The equilibrium of the capital market always exists and is always unique. The probability p that a run on short term debt happens and the share ν of entrepreneurs who choose a portfolio (α_2, μ_2) are given by*

$$\{p(\delta), \nu(\delta)\} = \begin{cases} \left\{\frac{\alpha_2 \mu_2}{\delta - \mu_2}; 1\right\} \text{ if } \delta \geq \mu_2 + \frac{\alpha_2 \mu_2}{q} \\ \left\{q; \frac{\delta - \mu_1}{\left(\frac{\alpha_2 + q}{q}\right)\mu_2 - \mu_1}\right\} \text{ if } \mu_1 < \delta \leq \mu_2 + \frac{\alpha_2 \mu_2}{q} \\ \{0; 0\} \text{ if } \delta \leq \mu_1 \end{cases}$$

Proof. cf. appendix. ■

There are three types of possible equilibria. First there can be a pure strategy equilibrium where all entrepreneurs choose strategy 2 (the risky strategy) and the ex ante probability that a run happens is $\frac{\alpha_2 \mu_2}{\delta - \mu_2}$. Second there can be a mixed strategy equilibrium where only a proportion $\nu = \frac{\delta - \mu_1}{\left(\frac{\alpha_2 + q}{q}\right)\mu_2 - \mu_1}$ of entrepreneurs choose strategy 2. Then the probability that a run happens is q. Thirdly there can be a pure strategy equilibrium where all entrepreneurs borrow δ per unit of own capital and the probability of a run on short term debt is zero.

5.2. Growth and macro-economic fluctuations.

Given the equilibria we have established, we can now compute the law of motion of the macroeconomic capital stock k as function of the wealth distribution $(w_l; w_e)$. The dynamics of the capital stock writes as

$$1+g=\begin{cases}\frac{r^2[w_l-(\nu(\delta)\mu_2+(1-\nu(\delta))\mu_1)w_e]+[\nu(\delta)(1+\mu_2)(R_s+w)+(1-\nu(\delta))(1+\mu_1)(R+w)]w_e}{w_e+w_l} \text{ if } \frac{w_l}{w_e}>\mu_1\\ R+w \text{ if } w_l\leq\mu_1 w_e\end{cases}$$

where R_s is equal to r with a probability $p(\delta)$ and R with a probability $1-p(\delta)$. We can then easily compute the mean and the variance of the growth rate of the capital stock as follows.

Proposition 2. *If $\delta>\mu_1$ the average growth rate of the economy Eg and the variance of the growth rate* $\operatorname{var}(g)$ *respectively write as*

$$1+Eg=\frac{\left[(1+\mu_2)\left[w+p(\delta)r+(1-p(\delta))R\right]+(\delta-\mu_2)r^2-(\mu_2-\mu_1)(1-\nu(\delta))w\right]}{1+\delta}$$

$$\operatorname{var}(g)=p(\delta)(1-p(\delta))\left(\frac{\nu(\delta)}{1+\delta}(1+\mu_2)(R-r)\right)^2$$

If $\delta\leq\mu_1$ then $Eg=w+R-1$ and $\operatorname{var}(g)=0$.

Proof: cf. appendix.

These expressions can be interpreted as follows. The expected growth rate is the sum of two terms: $\frac{(1+\mu_2)[w+p(\delta)r+(1-p(\delta))R]+(\delta-\mu_2)r^2}{1+\delta}$ is the pure strategy equilibrium expected growth rate and $(1-\nu(\delta))\frac{\mu_2-\mu_1}{1+\delta}w$ is the growth loss induced by the mixed strategy equilibrium. This loss is due to the fact that the threshold probability q is to low from a social point of view: a social planner who would take into account the externality of the capital stock of entrepreneurs on the technology of workers would more likely choose the risky financing strategy because it allows to invest more capital and hence to generate more income not only for entrepreneurs but also for workers. As to the growth rate variance it depends only upon the investments made in the production technology and financed with portfolios (α_2,μ_2) since those with portfolios (α_1,μ_1) are never subject to any run. At this stage, it is possible to study the variation of the expected growth rate

Eg_t against the volatility of the growth rate $\operatorname{var}(g_t)$. To this end we establish the following proposition.

Proposition 3. *In the mixed strategy equilibrium, expected growth decreases with δ and growth volatility increases with δ. In the pure strategy equilibrium case, expected growth increases with δ if and only if $\delta < \mu_2 + z_1$ and growth volatility increases with δ if and only if $\delta < \mu_2 + z_2$.*

Proof. cf. appendix.

In the pure strategy equilibrium case, an increase in δ has two effects. First the share of the macroeconomic capital stock invested in the storage technology increases. This decreases the expected growth rate because the storage technology has a relatively low return. Second an increase in δ reduces the probability that a run on short term debt occurs because the refinancing possibilities of lenders are larger. Therefore the investments made in the production technology are more productive on average. The proposition states that the first (negative) effect on average growth dominates for large values of δ while the second (positive) effect on average growth dominates for low values of δ. Growth volatility is also non monotonic w.r.t. δ because an increase the probability that a run on short term debt happens can increase or decrease growth volatility. In the mixed strategy equilibrium case, an increase in δ also has two effects. First as previously the share of the macroeconomic capital stock invested in the storage technology increases. This decreases the expected growth rate because the storage technology has a lower return. Second an increase in δ increases the proportion of entrepreneurs who choose the debt portfolio (α_2, μ_2). This increases the expected growth rate. However in the mixed strategy equilibrium, the first (negative) effect always dominates the second (positive) one. As to growth volatility, it increases with δ because only the second effect is relevant (the proportion of entrepreneurs who choose the debt portfolio (α_2, μ_2) increases). Therefore when δ is low ($\delta \leq \mu_2 + \frac{\alpha_2}{q}\mu_2$), the economy experiences mixed strategies equilibria and the correlation between growth volatility and average growth is negative. On the contrary when δ is large ($\delta \geq \mu_2 + \max\left\{z_1, z_2, \frac{\alpha_2}{q}\mu_2\right\}$), the economy experiences pure strategy equilibria and the correlation between growth volatility and average growth is positive[23].

[23] We focus on these two simple cases although the model has richer predictions because depending upon the parameters of the model, the case where $\mu_2 + \frac{\alpha_2}{q}\mu_2 \leq \delta \leq \mu_2 + \max\{z_1, z_2\}$ may not exist. In Figure 5, the diagram represents the case where $\max\{z_1, z_2\} > \frac{\alpha_2}{q}\mu_2$. The arrows in indicate the effect of a positive change in δ on average growth and growth volatility.

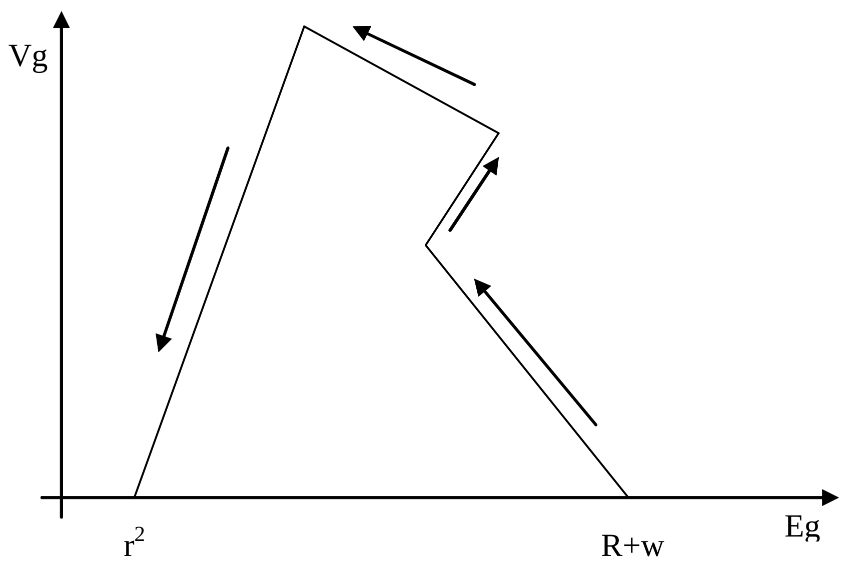

Figure 6: Growth Mean Volatility Diagram.

5.3. Empirical evidence.

In order to test the validity of the growth mean-volatility predictions of the model, we use data from two sources: The Penn world tables and the World Bank financial structure and economic development database. From the first source we get data on GDP. We use the GDP per capita in PPP as a measure of output per capita. We compute the growth rate of this variable and the mean and the standard deviation of the GDP per capita growth rate. From the financial structure and economic development database, we measure δ (the ratio of the financial sector to the non financial sector assets) with two proxies: the amount of liquid liabilities to GDP or alternatively the sum of financial intermediaries (central bank, deposit money banks and other financial institutions) assets to GDP. The model predicts that growth volatility is negatively related to average growth in countries where the financial sector assets are relatively small but positively related to growth in countries where the financial sector assets are relatively large. To test empirically this prediction, we estimate on a panel the determinants of the volatility of the GDP per capita growth *gvol*. We include as right hand side variables, the average GDP per capita growth rate g, a proxy for δ, an interaction term between these last two variables and control variables x.

$$gvol_{i,t} = \alpha_i + \beta_t + \gamma_1 \delta_{i,t} + \gamma_2 g_{i,t} + \gamma_3 \delta_{i,t} g_{i,t} + \lambda x_{i,t} + \varepsilon_{i,t}$$

To confirm the predictions of the theoretical model, we need that the coefficient of average growth be negative while that of the interaction term be positive $\gamma_2 < 0 < \gamma_3$. In line with previous empirical volatility studies, we introduce the log of the level of the GDP per capita in PPP as a control variable which is meant to capture that more developed economies are always less volatile. The econometric results follow.

Table 2. Dependent variable: standard deviation of GDP per capita growth.

Estimation	1	2	3	4	5	6	7	8	9	10	11	12
$g_{i,t}$	-0,25	-0,23	-0,38	-0,37	-0,11	-0,18	-0,24	-0,31	-0,00	-0,04	-0,04	-0,07
$ll_{i,t}$ ($\times 100$)			-0,42	-0,32			-0,43	-0,27			-0,11	-0,02
$g_{i,t} * ll_{i,t}$			0,44	0,39			0,28	0,33			0,10	0,11
$\log y_{i,t}$ ($\times 100$)		-0,31		-0,19		-0,16		-0,18		-0,06		-0,08
Adj. R-square	0,83	0,87	0,62	0,63	0,34	0,34	0,61	0,46	0,12	0,15	0,13	0,17

Table 3. Dependent variable: standard deviation of GDP per capita growth.

Estimation	1	2	3	4	5	6	7	8	9	10	11	12
$g_{i,t}$	-0,45	-0,39	-0,64	-0,59	-0,27	-0,35	-0,30	-0,52	-0,02	-0,08	-0,08	-0,13
$fia_{i,t}$ ($\times 100$)			-0,23	-0,32			-0,28	-0,22			-0,24	-0,18
$g_{i,t} * fia_{i,t}$			0,40	0,35			0,16	0,24			0,05	0,08
$\log y_{i,t}$ ($\times 100$)		-0,31		-0,04		-0,27		-0,31		-0,12		-0,09
Adj. R-square	0,87	0,66	0,81	0,62	0,72	0,61	0,56	0,74	0,12	0,24	0,29	0,32

Note: In Table 2 and 3, estimations 1-4 contain individual and time effects, estimations 5-8 contain fixed effects only and estimations 9-12 contain time effects only. In table 2, the sample includes 71 countries, 4 periods and 261 observations. In table 3, the sample includes 39 countries 4 periods and 136 observations. Both samples are unbalanced. Each time period covers 10 years from 1961 to 2000 (1961-1970, 1971-1980, 1981-1990, 1991-2000) on which the mean and standard deviation of the GDP per capita growth rate are computed. All equations have been estimated with an intercept and a correction for heteroscedasticity *à la White*. The average GDP per capita growth rate is $g_{i,t}$, the amount of liquid liabilities to GDP is $ll_{i,t}$, the ratio of financial intermediaries assets to GDP is $fia_{i,t}$ and $y_{i,t}$ is the level of GDP per capita in PPP. Beginning of period values have been considered for these last three variables. A ($\times 100$) after the variable name indicates that the coefficient reported is one hundred times the estimated parameter in the regression. All reported coefficients are significant at the 1% level except those in small characters which are not significant at the 5% level. The weighted adjusted R square is reported. Table 4 in the appendix reports descriptive statistics on the variables used in the estimations.

These estimations give us four results. First, the simple correlation between average growth and volatility is (almost) always significant and negative. This confirms the standard result of the growth volatility literature (Ramey and Ramey [1995]). Second the correlation between the development level (measured by the log of GDP per capita) and growth volatility is also always negative (but can be non significant). Economic development therefore reduces growth volatility (Acemoglu and Zilibotti [1997]). Thirdly the simple correlation between the size of financial intermediaries (measured by ll or fia) and volatility is (almost) always significant and negative. Finally the interaction term between growth and financial intermediaries assets is always significant and positive. Therefore the estimations deliver two different results. First an increase in financial intermediaries assets relatively to the rest of the economy reduces volatility, everything else equal, if and only if average growth is sufficiently low. In other words in economies with large average growth rates, financial development is likely to increase and not decrease growth volatility. Secondly, the econometric results confirm the predictions of the model as regards the growth volatility relationship: this relation is more likely to be negative in economies where financial intermediaries have a low level of assets relatively to the rest of the economy while it is more likely to be positive in economies where financial intermediaries have a high level of assets relatively to the rest of the economy.

6. Conclusion.

In this paper we have shown that macroeconomic fluctuations in the form of liquidity crises can emerge endogenously. When long term financial contracts are imperfectly enforceable and in the presence of interim moral hazard, lenders bias debt portfolios towards short term debt. They use this financial instrument to overcome the possibility for borrowers to default strategically. However this bias generates maturity mismatches between assets and liabilities and this can lead to global liquidity crises when projects are illiquid. Then, based on this microeconomic mechanism, we have obtained a theoretical result as concerns the correlation between growth volatility and average growth: it is more likely to be positive in economies where lenders are relatively well-endowed but more likely to be negative in economies where they are relatively ill-endowed. Finally we have brought some empirical evidence which confirms this view. This gives a new insight to the growth average-volatility debate showing that neither polar conception is likely to be coherent with the data.

7. Appendix.

7.1. Tables and figures.

var.	fia	g_2	sg_2	ll	g_3	sg_3
min.	6,10	0,19	0,01	7,00	-0,01	0,01
max.	258,63	3,94	8,51	181,14	3,96	8,51
mean	62,63	1,76	0,30	40,31	1,78	0,27
std.	45,46	0,94	0,75	24,53	1,03	0,57
med.	47,70	1,74	0,17	35,00	1,88	0,16

Table 4 : Descriptive Statistics[24].

[24] Variable names are the same as those used in table 2 and 3 expect for g_i which refers to average GDP per capita growth and sg_i which refers to the standard deviation of GDP per capita growth, the subscript i refering to the database used in table i. All figures are in percentage points.

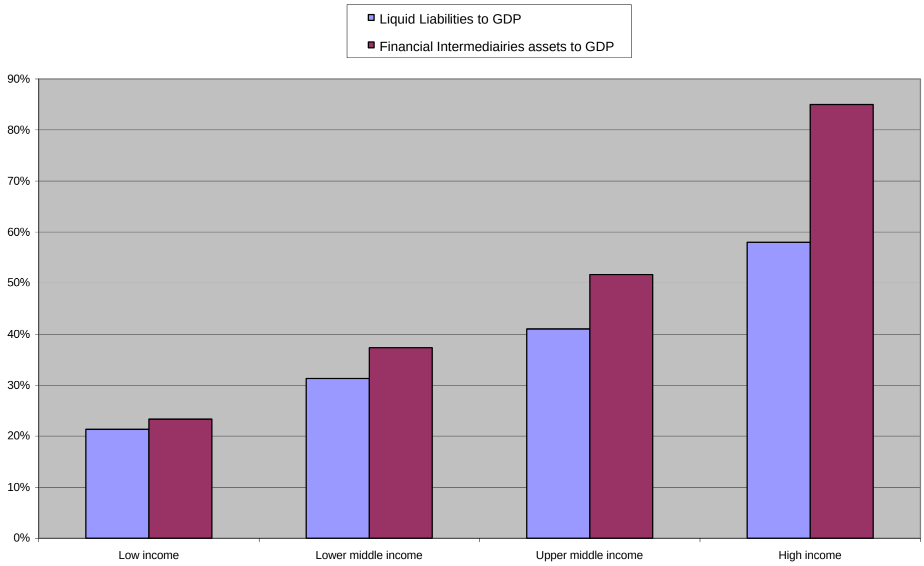

Figure 7: Financial Intermediaries size and income per capita.

Data from Beck, Demirgüç-Kunt and Levine [1999].

List of countries in the sample: Argentina, Australia, Austria*, Belgium*, Bolivia, BRB, Canada, Switzerland*, Chile*, Côte d'Ivoire*, CMR*, COG*, Colombia, CRI, Cyprus*, Denmark*, DOM*, Ecuador, Egypt, Spain, Ethiopia, Finland*, France, Gabon*, Great-Britain*, Ghana*, Gambia*, Greece, Guatemala, Guyana*, Honduras, India, Indonesia*, Irland, Iran, Island*, Italy*, Jamaica, Japan, Kenya*, South Korea, Sri Lanka*, MAR, Madagascar*, Mexico, MUS*, MYS, Nigeria, Netherlands, Norway, Nepal*, New-Zeland, Pakistan*, Panama*, Peru, Philipinnes, Portugal*, PRY, Rwanda, Senegal*, Slovenia*, Sweden, Syria*, Togo*, Thailand, Trinidad and Tobago, Taiwan, Uruguay*, USA, Venezuela and South Africa*.

Countries with stars are included in table 2 estimations but not in tables 3 estimations.

7.2. Incentive compatible contracts.

Let us consider a contract (α, μ). This contract must be such that entrepreneurs are better-off when they pay for their long term debts than when they default. When an entrepreneur is served a contract (α, μ) such that

$$\mu \leq \underline{\mu} = \frac{\tau' r}{(1-\alpha)\, r_l + \alpha \tau' r r_s - \tau' r}$$

then whatever his decision interim it is always more profitable for him to pay for his long term loans than to default. Now when $\mu > \underline{\mu}$, a necessary condition for an entrepreneur to pay for his long term loans is that he carries out his project and get the large return R. In this case his final profit is equal to

$$\overline{\pi} = (1 + \mu - \alpha\mu r_s)\, R - (1 - \alpha)\, \mu r_l$$

On the contrary if the entrepreneur decides to default on long term loans then he stops his project at the interim date and get the low return r. His final profit is then equal to

$$\underline{\pi} = (1 + \mu - \alpha\mu r_s)\,(1 - \tau')\, r$$

As is clear $\underline{\pi}$ is the largest profit entrepreneurs can reap when they default since $(1 - \tau')\, r > (1 - \tau)\, R$. Contracts (α, μ) which ensure that entrepreneurs pay for their long term liabilities therefore need that $\overline{\pi} \geq \underline{\pi}$ which, noting $\sigma = R - (1 - \tau')\, r$, simplifies as

$$\mu \leq \widehat{\mu} = \frac{\sigma}{(1 - \alpha)\, r_l + \alpha\sigma r_s - \sigma}$$

Finally since $\overline{\pi}$ is possible if and only if the illiquidity condition is verified, incentive compatible contracts (α, μ) verify $\mu \leq \underline{\mu}$ or

$$\begin{array}{c} \mu \leq \widehat{\mu} \\ \alpha\mu r_s \leq \eta\,(1 + \mu) \end{array} \quad \text{if } \mu > \underline{\mu}$$

7.3. Incentive compatible short term debt roll-over.

Let us consider the case of an entrepreneur who carries out a project in the production technology with a debt portfolio (α, μ). Then it is incentive compatible to exchange this portfolio against a portfolio (β, μ) if and only if

$$R\,(W + L - \beta r_s L) - (\alpha - \beta)\, r_{l,s} L - (1 - \alpha)\, r_l L \geq (1 - \tau)\, R\,(W + L - \beta r_s L)$$

If we note $\mu = \frac{L}{W}$, and under the assumption that $r_{l,s} > \tau R r_s$ this last expression can be simplified as

$$\beta \geq \frac{1}{r_{l,s} - \tau R r_s} \left[\alpha r_{l,s} + (1-\alpha) r_l - \tau R \frac{1+\mu}{\mu} \right]^+$$

where $[y]^+ = \max\{y; 0\}$. In this case the entrepreneurs debt portfolio (α, μ) becomes (β, μ).

7.4. Equilibrium of the capital market.

To determine the probability of a run on short term debt at the equilibrium, we need to write down the probability that is generated by entrepreneurs best response functions. Entrepreneurs best response functions write as

$$(\alpha^*, \mu^*) = \begin{cases} (\alpha_1, \mu_1) \text{ if } p > q \\ (\alpha_2, \mu_2) \text{ if } p < q \end{cases}$$

Given this function the resulting probability Γ that emerges from entrepreneurs choices writes as

$$\Gamma(p) = \begin{cases} \frac{\alpha_2 \mu_2}{[\delta - \mu_2]^+} \text{ if } p < q \\ 0 \text{ if } p > q \end{cases}$$

where $[y]^+ = \max\{y; 0\}$. Equilibria can then be identified with fixed points of the function $\Gamma(p)$. Since it is a non-increasing function of p, there is at most one fixed point an thereby one equilibrium. If $\frac{\alpha_2 \mu_2}{[\delta - \mu_2]^+} < q$ then there is a unique fixed point for $p = \frac{\alpha_2 \mu_2}{\delta - \mu_2}$. It is a pure strategy equilibrium where all entrepreneurs choose contracts (α_2, μ_2) $(\nu = 1)$. This case is possible if and only if $\delta \geq \mu_2 + \frac{\alpha_2}{q} \mu_2$. On the contrary if $\frac{\alpha_2 \mu_2}{[\delta - \mu_2]^+} > q$ then Γ has no fixed point and we look for mixed strategies equilibria. Given the definitions adopted as to how financial contracts determine the probability of a run on short term debts, a mixed strategies equilibrium is a proportion ν which solves the equation $q = \frac{\nu \alpha_2 \mu_2}{[\delta - \nu \mu_2 - (1-\nu)\mu_1]^+}$. Given that the right hand side is a continuous strictly increasing function in ν on $\left[0, \frac{\alpha_2 \mu_2}{\delta - \mu_2}\right]$ there is a unique solution to this equation.

$$\nu = \frac{\delta - \mu_1}{\frac{\alpha_2}{q} \mu_2 + \mu_2 - \mu_1}$$

This last case is possible if and only if $\mu_1 < \delta \leq \left(1 + \frac{\alpha_2}{q}\right)\mu_2$. Finally when $\delta \leq \mu_1$ entrepreneurs cannot collectively borrow nor μ_1 nor μ_2. The economy is short of financial capital. Then all entrepreneurs borrow δ per unit of own capital and the probability that a run occurs is zero.

7.5. Expected growth and growth variance expressions.

If $w_l - \mu_1 w_e \geq 0$ the growth rate of the economy g_{t+2} writes as

$$1 + g = \frac{\nu\,(1+\mu_2)\,w_e\,(R_s + w) + (1-\nu)\,(1+\mu_1)\,w_e\,(R+w) + [w_l - \nu\mu_2 w_e - (1-\nu)\,\mu_1 w_e]\,r^2}{w_l + w_e}$$

where $R_s = r$ with a probability p and $R_s = R$ with a probability $1-p$. If $w_l - \mu_1 w_e < 0$ then all the capital stock of the economy is invested in the illiquid technology whose return is then always equal to R. Therefore when $w_l - \mu_1 w_e < 0$ the growth rate of the economy is equal to $w + R$. On the contrary when $w_l - \mu_1 w_e \geq 0$, the average growth rate Eg and the growth rate variance $\operatorname{var}(g)$ are respectively equal to

$$1 + Eg = \frac{w_e}{w_l + w_e}\left[\nu\,(1+\mu_2)\,[w + pr + (1-p)\,R] + (1-\nu)\,(1+\mu_1)\,(R+w) + \left[\frac{w_l}{w_e} - \nu\mu_2 - (1-\nu)\,\mu_1\right] r^2\right]$$

$$\operatorname{var}(g) = p\,(1-p)\left(\frac{w_e}{w_l + w_e}\right)^2 [\nu\,(1+\mu_2)\,(R-r)]^2$$

Then since $\frac{w_l}{w_e} = \delta$, and using the property that $q = \frac{\mu_2 - \mu_1}{1+\mu_2}\frac{R-r^2}{R-r}$ in the mixed strategy equilibrium we have

$$1 + Eg = \frac{(1+\mu_2)\,[w + p\,(\delta)\,r + (1-p\,(\delta))\,R] + [\delta - \mu_2]\,r^2 - (1-\nu\,(\delta))\,(\mu_2 - \mu_1)\,w}{1+\delta}$$

$$\operatorname{var}(g) = p\,(\delta)\,(1-p\,(\delta))\left(\frac{\nu\,(\delta)}{1+\delta}\,(1+\mu_2)\,(R-r)\right)^2$$

7.6. Variations of volatility and expected growth.

In the mixed strategy equilibrium we have

$$\frac{\partial\,\mathrm{E}\,g}{\partial\delta} = -\frac{(1+\mu_1)\,(R-r)}{\left(\frac{\alpha_2}{q}\mu_2 + \mu_2 - \mu_1\right)(1+\delta)^2}\left[\frac{\alpha_2}{q}\frac{R-r^2}{R-r}\mu_2 + (\mu_2 - \mu_1)\,\frac{R-r^2}{R-r}\right]$$

This quantity is always negative: expected growth decreases with δ. In the pure strategy equilibrium we have

$$\frac{\partial \operatorname{E} g}{\partial \delta} = \frac{(1+\mu_2)}{(1+\delta)^2}(R-r)\left[\left[\frac{1+\delta}{\delta-\mu_2}+1\right]p(\delta) - \frac{R-r^2}{R-r}\right]$$

It is positive if and only if $\frac{R-r}{R-r^2}p(\delta)\left[1+\frac{\delta+1}{\delta-\mu_2}\right] > 1$ which simplifies as $\delta - \mu_2 < z_1$ with

$$z_1 = \frac{R-r}{R-r^2}\alpha_2\mu_2 + \sqrt{\left[\frac{R-r}{R-r^2}\alpha_2\mu_2\right]^2 + \frac{R-r}{R-r^2}(1+\mu_2)\alpha_2\mu_2}$$

As to the variance of the gross growth rate, in the mixed strategy equilibrium we have

$$\frac{\partial \operatorname{var}(g)}{\partial \delta} = 2\frac{\nu(\delta)}{(1+\delta)^3}q(1-q)\left((1+\mu_2)(R-r)\right)^2\frac{1+\mu_1}{\mu_2-\mu_1+\frac{\alpha_2\mu_2}{q}}$$

which is always positive. In the pure strategy equilibrium we have

$$\frac{\partial \operatorname{var}(g)}{\partial \delta} = \frac{p(\delta)}{(1+\delta)^3}\left[\left[\frac{1+\delta}{\delta-\mu_2}+1\right](2p(\delta)-1)-1\right]\left((1+\mu_2)(R-r)\right)^2$$

It is positive if and only if $[2p(\delta)-1]\left[1+\frac{\delta+1}{\delta-\mu}\right] > 1$ which simplifies as $\delta - \mu_2 < z_2$

$$z_2 = \frac{1+\mu_2-4\alpha_2\mu_2}{6} + \sqrt{\left[\frac{1+\mu_2-4\alpha_2\mu_2}{6}\right]^2 + \frac{2}{3}(1+\mu_2)\alpha_2\mu_2}$$

7.7. Dynamics of the economy.

Let us note θ_t the indicator variable which takes a value 1 if a run happens at date t and 0 otherwise. Then the ratio of lenders to borrowers wealth δ follows the following law of motion:

$$\delta_{t+2}(\theta_{t+1}) = \begin{cases} \left(1+\frac{w}{R}\right)\delta_t + \frac{w}{R} \text{ if } \delta_t \leq \mu_1 \\ \frac{(1+\nu(\delta_t)\mu_2+(1-\nu(\delta_t))\mu_1)w+r^2\delta_t}{\nu(\delta_t)[(1+\mu_2)R(\theta_{t+1})-\mu_2 r^2]+(1-\nu(\delta_t))[(1+\mu_1)R-\mu_1 r^2]} \text{ if } \mu_1 \leq \delta_t \leq \left(\frac{\alpha_2+q}{q}\right)\mu_2 \\ \frac{(1+\mu_2)w+r^2\delta_t}{(1+\mu_2)R(\theta_{t+1})-\mu_2 r^2} \text{ if } \delta_t \geq \left(\frac{\alpha_2+q}{q}\right)\mu_2 \end{cases}$$

where $R(0) = R$, $R(1) = r$ and $\Pr(\theta_{t+1} = 1) = p(\delta_t)$. Since $w > 0$ and $R > 0$ any steady state of the economy δ^* is such that $\delta^* > \mu_1$. There is no degenerate steady state where $\delta^* = 0$.

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