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Abstract

Using a multi-country general equilibrium model, we demonstrate that when agents face credit constraints in an international financial market, rational expectations, which are ex-post heterogeneous between countries, cause business fluctuations. If the international financial market becomes perfect, only a unique perfect foresight equilibrium is obtained, implying that no business fluctuations appear.

Keywords: Business fluctuations; Financial globalization; Sunspots; Heterogeneous agents; Rational expectations.

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1 Introduction

When do sunspots matter in an international economy? This question is important in the era of financial globalization. The ongoing financial globalization has been encouraged by the reduction of capital controls in successfully industrialized countries that have been participants in the international financial market only since the mid-1980s, such as East Asian countries and regions.[1] In an era of financial globalization, capital moves instantly between countries, seeking advantageous opportunities for profits.

Due to the instantaneous movement of capital, a number of countries have often become the victims of financial crises that were followed by serious economic downturns. Major financial crises in the 20th and 21st centuries, such as the Latin American debt crisis in the early 1980s, the Asian financial crisis in 1997, and the subprime loan crisis in the United States in the late 2000s, seemed to occur even though major economic indices, such as growth rates and inflation rates, were not unfavorable immediately before the crises. In particular, in the 1980s and 1990s, many middle-income countries faced a sudden capital reflux followed by a severe economic slump. The financial crises often seemed to be caused not by fundamental variables but by human psychology in an international financial market. In other words, sunspots or animal spirits do matter to the international economy.

In this paper, by developing a multiple country general equilibrium model, we demonstrate that when individuals face financial market imperfections, the international economy becomes unstable with respect to the allocation of input, and the production of final goods becomes tenuous, both of which result from the movement of capital that is caused by the social psychology of individuals and the sentiment of a financial intermediary.

Many researchers have emphasized the importance of expectations in understanding macroeconomic phenomena. For instance, since Azariadis (1981) and Cass and Shell (1983),

[1] The acceleration of financial globalization in the mid-1980s is the second wave of the free movement of capital between countries. By 1914, financial globalization had advanced such that capital moved freely across borders, the level of which was never or barely achieved even in 1990. See Eichengreen (2003) and Obstfeld and Taylor (2004).

it has been an accepted truth that, in a general equilibrium model, randomization of multiple perfect foresight equilibria by agents' psychology or "sunspots" create endogenous business fluctuations. Therefore, in the literature on the endogenous business fluctuations that are induced by sunspots, researchers have focused their studies on the indeterminacy of perfect foresight equilibria, which is a sufficient condition for sunspots to appear.[2]

Meanwhile, Cass and Shell (1983) have also discovered that although equilibrium is unique, it is possible that sunspots do matter when agents have heterogeneous expectations. Our model is closely related to their seminal discovery in that sunspots do not originate from the randomization of multiple equilibria but from heterogeneous expectations.

To the best of our knowledge, only Krasker (1984) directly follows the discovery of Cass and Shell (1983) and deals with heterogeneous expectations in a general equilibrium setting, although for sunspots to matter, heterogeneous expectations are important. Krasker (1984) investigates an overlapping generations economy with production when individuals have heterogeneous expectations about extrinsic uncertainty, and he clarifies how capital accumulation is affected by heterogeneous expectations. However, since the capital market is perfect in Krasker's model, heterogeneous expectations must then be irrational to be incorporated into Diamond's overlapping generations model (Diamond 1965).[3] By contrast, in our model, since the international financial market is imperfect, we can incorporate into a general equilibrium model rational expectations that are ex-post heterogeneous between countries.

Our findings are as follows: When the international financial market is perfect, extrinsic uncertainty does not matter to the real economy, implying that agents' minds or the sentiment of the financial intermediary are not affected by sunspots and thus the allocation of economic resources is unique and Pareto optimal. Of course, the uniqueness and Pareto op-

[2]See for instance Benhabib and Farmer (1994, 1996), Benhabib and Nishimura (1998) for multiple equilibria induced by externality. See also Howitt and McAfee (1992) for multiple equilibria induced by friction of search behavior.

[3]That is why he states that "[his] framework is, in fact, not quite a general equilibrium model." Actually, however, his framework is a general equilibrium model with irrational expectations.

timality of allocation in a general equilibrium model with a perfect market is not surprising. However, if the international financial market is imperfect, then sunspot events affect agents' minds as well as the sentiment of the financial intermediary, which cause instability in the international economy.

Meanwhile, when an economy with an imperfect financial market is closed to the world market, the allocation of production input is unique, while the distribution of output among agents is affected by extrinsic uncertainty. In other words, only inequality within a country is subject to sunspot events.

The importance of financial market imperfections in understanding macroeconomic instability has been emphasized ever since the seminal paper by Bernanke and Gertler (1989).[4] However, only a few researchers have investigated endogenous fluctuations induced by sunspots in a multiple country model with financial market imperfections. Hu and Mino (2009) deal with a two-good, two-factor, two-country model with infinitely lived agents. They incorporate an international financial market as well as an international trade market into their model. Differing from our model, they provide a condition for local sunspots induced by the randomization of multiple equilibria.

Even without incorporating financial market imperfections, very few papers deal with endogenous business fluctuations with sunspots in a multi-country model, although there are some exceptions including Nishimura and Yano (1993) and Aloi and Lloyd-Braga (2010). Nishimura and Yano (1993) derive endogenous business fluctuations using a two-good, two-factor, two-country model with infinitely lived agents. They focus on the relationship between international trade and business cycles. However, because an international financial market is not incorporated in their model, they do not investigate the effects of financial globalization on the world economy. In contrast, Aloi and Lloyd-Braga (2010) establish a model in which two countries are financially integrated, and they investigate how economic volatility induced by labor market imperfections spreads to the other country.

[4] See also Boyd and Smith (1997), Kiyotaki and Moore (1997), Aghion, et al. (1999) and Matsuyama (2004, 2007).

None of these articles consider heterogeneous agents within a country or heterogeneous expectations between countries. Heterogeneous talents and heterogeneous expectations are important in our model (as are financial market imperfections) for sunspots to matter.

This paper proceeds as follows: In the next section, we provide a basic model. In section 3, we derive equilibrium and discuss both a perfect foresight equilibrium and a sunspot equilibrium. In section 4, we discuss when sunspots do matter in the international economy and consider the constrained optimality of the international economy. Concluding remarks are presented in section 5.

2 Model

The international economy consists of N countries indexed by i ($i = 1, ..., N$), and it continues for two consecutive time periods. Each country consists of individuals who live for two periods. As will be seen later, individuals are heterogeneous in their talents to create consumption goods. There is a representative financial intermediary that is conducting business in the international financial market. The financial intermediary accepts deposits from individuals and loans financial resources to investors wherever they live. Each country is ex-ante identical except that they may have different rational expectations for the future interest rate. The population in each country is normalized to one.

The time schedule related to agents' decision-making is summarized in figure 1. Agents are born at the beginning of the first period, and then $E(r)$ is announced by the financial intermediary or the domestic media, where $E(r)$ is the mathematical mean of the future interest rate.[5] In our model, a mathematical mean of a random variable, $X(\omega)$, is computed over sunspot events $\{\omega\}$, where $\{\omega \in \Omega \mid X(\omega) \leq x\}$ is an element of a σ-algebra $\mathcal{F}$ of a fixed probability space $(\Omega, \mathcal{F}, P)$. If $X(\omega)$ is constant almost everywhere (a.e.) in $(\Omega, \mathcal{F}, P)$, then it is a deterministic variable.

[5]Alternatively, we may assume that each individual computes $E(r)$ with knowledge of our model. In the main text, one could imagine, for instance, that a think tank could provide individuals with the information about $E(r)$.

Once $E(r)$ is announced, the international financial market is opened, but then a sunspot event is observed. The sunspot event is reflected in agents' minds. Then, in each country, the country-specific expectation for the future interest rate, r^{ie}, is noted, and the investment decisions are made by agents. At the end of the first period, the financial market is closed.

At the beginning of the second period, consumption goods are produced. Then, the second sunspot event occurs, which affects the sentiment of the financial intermediary and r is fulfilled. The second sunspot event comes out of the same probability space as that of the first sunspot event. The two sunspots are independent of each other. At the end of the second period, each agent consumes all his income after repayments.

2.1 Individuals

In the first period, an agent in country i is born with an endowment w. He/she is risk-neutral and he/she exclusively obtains his/her utility from his/her second period consumption. Because the endowment is perishable in one period, he/she will invest it in a project or deposit it with the financial intermediary. If he/she wants to borrow financial resources from the financial intermediary, the financial intermediary will lend him/her up to some proportion of his/her initial wealth, namely, the financial intermediary imposes a credit constraint on borrowing.

If an agent invests one unit of his/her endowment in a project in the first period, then he/she will create ϕ units of consumption goods in the second period, where ϕ is the constant marginal product of his/her investment. Meanwhile, if he/she deposits his/her endowment with the financial intermediary in the first period, then he/she will obtain r units of consumption goods in the second period, where r is the gross interest rate of his/her deposit. When an agent makes a decision on how much he/she invests in a project or deposits in the financial intermediary, he/she cannot generically observe the future interest rate r. Therefore, he/she has an expectation of what the future interest rate will be when he/she has to make a decision. We assume that the expectation for the future interest rate is identical between agents within a country, whereas it may vary between countries.

An agent in country i maximizes his/her expected consumption in the second period, c^{ie}, subject to:

$$k^i + b^i \leq w \tag{1}$$

$$c^{ie} \leq \phi k^i + r^{ie} b^i \tag{2}$$

$$b^i \geq -\eta w, \qquad 0 < \eta < \infty. \tag{3}$$

Inequality (1) is a budget constraint in the first period, where k^i is an investment and b^i is a deposit if positive and a debt if negative. Inequality (2) is the budget constraint in the second period, where r^{ie} is the expectation for the future interest rate. As mentioned above, if an agent invests in a project, he/she creates consumption goods, whereas if he/she deposits his/her endowment with the financial intermediary, he/she is repaid with interest in the second period. If he/she borrows from the financial intermediary, then he/she has to repay it with interest. He/she consumes all of the income in the second period. Inequality (3) is a credit constraint. Following Aghion et al. (1999), Aghion and Barnergee (2005), and Aghion et al. (2005), we assume that an agent can borrow financial resources from the financial intermediary up to η times his/her initial wealth.[6] As η increases, the credit constraint is relaxed. In particular, if η goes to infinity, the financial market becomes perfect.[7] It should be noted that w and η are invariant between countries without being indexed by i.[8]

Now we introduce the heterogeneity for ϕ between individuals. ϕ has a uniform distribution $G(\phi)$ whose support is $[0, a]$ ($a > 0$), implying that $G'(\phi) = \frac{1}{a}$ if $\phi \in [0, a]$. Lemma 1 below provides a solution for the maximization problem for individuals.

Lemma 1 *(1) If $\phi < r^{ie}$, then $k^i = 0$ and $b^i = w$. (2) If $\phi > r^{ie}$, then $k^i = \frac{w}{1-\mu}$ and $b^i = -\frac{\mu w}{1-\mu}$.*

[6] In the appendix, we provide a simple microfoundation for credit constraints along the same line of Antrás and Caballero (2009).

[7] In other words, in this case, each agent can borrow up to the natural debt limit.

[8] These assumptions can be relaxed by letting w and η be country-specific; however, the analysis would then be complicated without any advantage for the claimed results.

Proof: The maximization problem is rewritten as:

$$\max_{b^i}(r^{ie} - \phi)b^i$$

subject to

$$-\frac{\mu}{1-\mu}w \leq b^i \leq w,$$

where $\mu := \frac{\eta}{1+\eta}$. From this problem, if $r^{ie} - \phi > 0$, then it is optimal for an individual to choose $b^i = w$ and $k^i = 0$, whereas if $r^{ie} - \phi < 0$, then it is optimal to choose $b^i = -\frac{\mu w}{1-\mu}$ and $k^i = \frac{w}{1-\mu}$. □

From lemma 1, we note that r^{ie} is the cutoff that divides agents into savers and investors. The (per capita) production of consumption goods in country i is given by:

$$Y_t^i := \int_{r^{ie}}^{a} \frac{w}{1-\mu}\phi dG(\phi) = \frac{F(r^{ie})}{1-\mu}w, \tag{4}$$

where $F(r^{ie}) := \int_{r^{ie}}^{a} \phi dG(\phi) = \frac{1}{a}(a^2 - (r^{ie})^2)$. The per capita output is a decreasing function of the expectation for the future interest rate.

2.2 Financial Intermediary

Because the international financial market is competitive, the representative financial intermediary cannot profit from it. Because the financial intermediary does not have an initial net worth, it only accommodates borrowers with loans and accept deposits from savers so that the liabilities (which contain only the total deposit) and the assets (which contains only the total loan) are balanced on its balance sheet. In the second period, it places the interest rate at r so that the goods and financial markets clear. Let $E(r)$ be the mathematical mean of the interest rate. Then we obtain:

$$r = E(r) + \epsilon, \tag{5}$$

where ϵ is the error term with mean zero. ϵ is $\mathcal{F}$-measurable and is a continuous random variable. The error term ϵ comes from the extrinsic uncertainty associated with the sentiment of the financial intermediary in the second period. We assume that ϵ is continuous in the support $[\epsilon_L, \epsilon_H]$ where $\epsilon_L \leq 0 \leq \epsilon_H$. We also assume that $a\mu + \epsilon_L > 0$ so that the equilibrium interest rate r is always greater than zero. When $\epsilon_L = \epsilon_H = 0$, ϵ, and thus, r become deterministic variables. When it holds that $\epsilon_L < 0 < \epsilon_H$, ϵ is a random variable. Individuals cannot observe the sentiment of the financial intermediary ϵ when they make decisions on an investment.

2.3 Market Clearing Condition

Let B^i be the net foreign wealth held by country i in the first period. B^i is given by the total saving minus the total loan in country. From lemma 1, we obtain:

$$\begin{aligned} B^i &= \int_0^{r^{ie}} w dG(\phi) - \int_{r^{ie}}^{a} \frac{\mu w}{1-\mu} dG(\phi) \\ &= \frac{G(r^{ie}) - \mu}{1-\mu} w. \end{aligned} \tag{6}$$

We note from Eq.(6) that country i is a net borrower (creditor) in the international financial market if and only if $G(r^{ie}) < (>) \mu$.

Now suppose that all countries are financially integrated. Because the financial market should clear across the countries, it always holds that $\sum_{i=1}^{N} B^i = 0$ or equivalently:

$$\sum_{i=1}^{N} G(r^{ie}) = N\mu. \tag{7}$$

3 Equilibrium

If the financial intermediary sets a very high interest rate, then there is a possibility that some borrowers may default and the financial market does not clear even though the financial intermediary imposes credit constraints. We assume away this case, i.e., we assume that the sentiment of the financial intermediary appears such that no one experiences bankruptcy.

In what follows to the end, we consider only rational expectations equilibria in the sense that on average, the expectation for the future interest rate is equal to the actual interest rate, i.e., $E(r^{ie}) = E(r)$ before the sunspot events. In other words, individuals should not make systematic errors because they minimize $E(r - r^{ie})^2$, whose first-order condition is given by $E(r^{ie}) = E(r)$.

Definition 1 *A rational expectations equilibrium in the international economy is expressed by an interest rate r, the expectations for the interest rate $\{r^{ie}\}$ $i = 1, ..., N$ where $E(r^{ie}) = E(r)$ before the sunspot events, and allocation $\{c^i, k^i, b^i\}$ for each i and ϕ such that (i) for each $\phi \in [0, a]$ in country i and given r^{ie}, $\{k^i, b^i\}$ solves the maximization problems of individuals and (ii) all markets clear such that there are no bankruptcies.*

A perfect foresight equilibrium in which $r^{ie} = r$ a.e. is a special case of a rational expectations equilibrium.

3.1 Perfect Foresight Case

In this section, we derive an equilibrium in which all the agents have perfect foresight of the future interest rate such that it always holds that $r^{ie} = r$ a.e. for $i = 1, ..., N$.

Proposition 1 *Suppose that all agents in the world have perfect foresight of the future interest rate. Then, the interest rate is deterministic, implying that extrinsic uncertainty does not matter to the real economy.*

Proof: Since $r^{ie} = r$ a.e., we have $G(r) = \mu \Longleftrightarrow r = a\mu$ a.e. from Eq.(7). This implies that r is a deterministic variable and is determined by the economic fundamentals. Therefore, extrinsic uncertainty does not matter to the real economy. $\square$

In the case of perfect foresight, equilibrium is unique. We note from Eq.(6) that the net foreign wealth in all the countries is zero, and they produce the same amount of consumption goods. This is because they are perfectly symmetric. The international economy is stable without being affected by agents' psychology or the sentiment of the financial intermediary.

3.2 Market Psychology and Business Fluctuations

Now, we relax the assumption of perfect foresight and investigate business fluctuations induced by agents' expectations. If we assume away the assumption of perfect foresight of the future interest rate, then it is possible that an infinite number of interest rates could exist that support the equilibrium allocation of economic resources allocated in the first period. To see this intuitively, we can aggregate the budget constraint in the second period in country i:

$$C^i = Y^i + rB^i, \tag{8}$$

where the capital notations stand for the aggregate variables in country i. The aggregation of Eq.(8) across the world yields:

$$\sum_{i=1}^{N} C^i = \sum_{i=1}^{N} Y^i + r \sum_{i=1}^{N} B^i. \tag{9}$$

Because the international financial market should clear, it follows that $\sum_{i=1}^{N} B^i = 0$. This means that the market clearing condition is independent of the world interest rate, r, once the expectations of the future interest rate are confirmed at time t.

Meanwhile, there is an upper limit to the actual world interest rate, which is restricted by a non-bankruptcy condition of borrowers.

Lemma 2 *Given r^{ie} for $i = 1, ..., N$, the necessary condition for r to be an equilibrium interest rate is that $r \in \bigcap_{i=1}^{N} [0, \frac{r^{ie}}{\mu}]$.*

Proof: Suppose that $r > \frac{r^{ie}}{\mu}$ for some i. Then, the income of the agents with $\phi \in (r^{ie}, \mu r)$ at the second period is $(\phi - \mu r)k < (\mu r - \mu r)k = 0$, which contradicts a non-bankruptcy condition. $\square$

We note that $r^{ie} \geq \mu r$ for all i. Lemma 2 tells us that there is no guarantee that the expectation of the future interest rate is equal to the actual one, although all the agents know the structure of the current model. This fact affects the equilibrium allocation of economic resources when the expectations of the future interest rate in each country are different from each other.

Now, we assume the expectation formation of the future interest rate. At the beginning of the first period, each agent knows the mathematical mean of the interest rate $E(r)$. One may think that private agents have been informed of $E(r)$ by the domestic media or the financial intermediary. At the time when the private agents contract with the financial intermediary, they do not know the actual real interest rate of r, which will have been accidentally determined in the second period due to extrinsic uncertainty.

Private agents in a country have expectations of the future interest rate based on $E(r)$, which is the only information on the future interest rate. Their expectation formation is disturbed by country-specific noises in the first period. The formation of expectations of the future interest rate is assumed as follows:

$$r^{ie} = E(r) + \lambda^i, \tag{10}$$

where λ^i is the country-specific error term with mean zero, given the information in the first period. λ^i is a continuous random variable, which is $\mathcal{F}$-measurable. $\lambda^i - \epsilon$ expresses the miscapture of the error term ϵ.[9]

To derive $E(r)$, we take a mathematical expectation for both sides of Eq.(7) and obtain $NE(r) = aN\mu \Longleftrightarrow E(r) = a\mu$. From this, we have:

$$r = a\mu + \epsilon \tag{11}$$

$$r^{ie} = a\mu + \lambda^i. \tag{12}$$

Proposition 2 *(1) If μ is sufficiently close to one, then $r = r^{ie} = a$, implying that there exists only a perfect foresight equilibrium. (2) If μ is sufficiently close to zero, then $r^{ie} = 0$, implying that there exists only an autarky equilibrium without a financial sector.*

Proof: From lemma 2 and Eqs.(11) and (12), we obtain:

$$\lambda^i \geq \mu\epsilon - (1-\mu)a\mu. \tag{13}$$

From Eq.(13), it holds that for $i = 1, ..., N$, $\lambda^i \geq \lim_{\mu\to 1}(\mu\epsilon - (1-\mu)G^{-1}(\mu)) = \epsilon$. Since $E(\lambda^i) = E(\epsilon) = 0$, it must follow that $\lambda^i = \epsilon$ a.e. for $i = 1, ..., N$. Therefore, the case is

[9] One could assume that λ^i has the same distribution as that of ϵ. In this case, we can say that individuals know the exact distribution of the disturbance of the sentiment of the financial intermediary.

one of perfect foresight, and thus, the first part of proposition 2 holds. For the second part, because $\lambda^i \geq \lim_{\mu \to 0}(\mu\epsilon - (1-\mu)a\mu) = 0$, λ^i must be a deterministic variable and is given by $\lambda^i = 0$ a.e. for $i = 1, ..., N$, which leads to $r^{ie} = 0$ a.e. In this case, every agent in every country creates consumption goods for him/herself. $\square$

Regarding the first part of proposition 2, we intuitively say that when the international financial market is perfect, the corner solution obtained in the maximization problem of each individual is consistent with a unique allocation of the world economy, which is Pareto optimal. However, when $0 < \mu < 1$, an equilibrium allocation of the world economy is not Pareto optimal. In this case, as observed later, there exist the random variables of λ^i and ϵ, which reflect agents' psychology and the sentiment of the financial intermediary, respectively.

Henceforth, we focus our study on the case in which $r^{ie} \leq a$. While r^{ie} could be greater than a, it is only when r^{ie} is in $[0, a]$ that the output of each country varies. This is because if r^{ie} is greater than a, $F(r^{ie})$ is equal to zero. Investigating these cases makes our study very complicated while the main points of our model remain unchanged.

Lemma 3 $\sum_{i=1}^{N} \lambda^i = 0$.

Proof: Substituting Eq.(12) into Eq.(7), we obtain $aN\mu + \sum_{i=1}^{N} \lambda^i = aN\mu$. $\square$

Lemma 3 implies that λ^i $(i = 1, ..., N)$ can vary with the $N-1$ degrees of freedom. In particular, it follows from Eq.(6) that if $\lambda^i > 0$ (< 0), then country i is a net creditor (borrower) in the international financial market. In the international financial market, it is impossible that all of the countries become net creditors or borrowers. That is why the degrees of freedom of $\{\lambda^i\}$ are $N-1$, not N. We also note from lemma 3 that if the formation of rational expectations is homogeneous among countries, then it must follow that $\lambda^1 = \lambda^2 = ... = \lambda^N = 0$.

Proposition 3 *Suppose that* $0 < \mu < 1$ *and define* $\lambda_H := min\{a(1-\mu), (N-1)\mu(a(1-\mu) - \epsilon^H)\}$. *If* $0 < \epsilon^H < (1-\mu)a$, *then there exist both a random variable* ϵ *and random variables* $\{\lambda^1, ..., \lambda^N\}$ *such that* $\sum_{i=1}^{N} \lambda^i = 0$ *and the support for each* λ^i *is given by* $I :=$

$[\mu(\epsilon^H - a(1-\mu)), \lambda_H]$. *In particular,* $\mu(\epsilon^H - a(1-\mu))$ *and* λ_H *are the minimum and maximum values that* λ^i *can take.*

Proof: If $0 < \epsilon^H < (1-\mu)a$, we can construct a random variable such that the support of ϵ is $[\epsilon^L, \epsilon^H]$, where $\epsilon^L < 0 < \epsilon^H$. Because $\epsilon^H - a(1-\mu)$ is negative, we can let the lower limit of the support of λ^i be $\mu(\epsilon^H - a(1-\mu))$ such that for any realization of ϵ, Eq.(13) holds. This implies that the minimum value of λ^i for each i could be $\mu(\epsilon^H - a(1-\mu))$. Pick any integer $j \in [1, N]$. Suppose that $\lambda^i = \mu(\epsilon^H - a(1-\mu))$ for each i except for j. Then, it must hold that $\lambda^j = (N-1)\mu(a(1-\mu) - \epsilon^H)$ because $\sum_{i=1}^N \lambda^i = 0$. If $\lambda^j = (N-1)\mu(a(1-\mu) - \epsilon^H) \leq a(1-\mu)$, then it is the maximum value of λ^j. However, if $\lambda^j = (N-1)\mu(a(1-\mu) - \epsilon^H) > a(1-\mu)$, then the maximum value of λ^j is $a(1-\mu)$ because $r^{ie} = a\mu + \lambda^i \leq a$. (In this case, not all of the λ^i $(i \neq j)$ can take the value $\lambda^i = \mu(\epsilon^H - a(1-\mu))$). $\square$

From lemma 3, the random variables $\{\lambda_1, ..., \lambda_N\}$ are linearly dependent and the degrees of freedom are $N-1$. Their realizations should be on a subset of a hyperplane such that $\{(\lambda_1, ..., \lambda_N) \in \Re^N | \sum_{i=1}^N \lambda^i = 0, \;\; \mu(\epsilon^H - a(1-\mu)) \leq \lambda^i \leq \lambda_H \text{ for each } i\}$. As stated above, for the international financial market to clear, some countries will face capital inflow whereas the other countries will experience capital outflow depending on the psychology of each country. Figure 2 provides a graphic illustration when $N = 3$ and $\lambda_H = (N-1)\mu(a(1-\mu) - \epsilon^H$.

When ϵ^H is given such that the condition of proposition 3 is satisfied, μ takes a value in $(0, \frac{a-\epsilon^H}{a})$. An interesting question is at what value of μ $|I| = min\{-a\mu^2 - \epsilon\mu + a, -Na\mu(\mu - \frac{a-\epsilon^H}{a})\}$ is maximized. This question is related to the maximum amplitude of fluctuations of the international economy.

Proposition 4 *Suppose that* ϵ^H *is given such that the condition of proposition 3 is satisfied and* μ *is in* $(0, \frac{a-\epsilon^H}{a})$. *Then, the following should hold: (1) If* $N(a-\epsilon^H)^2 \leq 3a^2 + (\epsilon^H)^2$, *then* $|I|$ *is maximized at* $\mu = \frac{a-\epsilon^H}{2a}$ *and (2) if* $N(a-\epsilon^H)^2 > 3a^2 + (\epsilon^H)^2$, *then* $|I|$ *is maximized at* $\mu = \frac{aN - \epsilon^H(N-1) - 4\sqrt{a^2(N-1)}}{2(N-1)a}$.

Proof: Let $f(\mu) := -Na\mu(\mu - \frac{a-\epsilon^H}{a})$ and $g(\mu) := -a\mu^2 - \epsilon\mu + a$. The maximum of

$f(\mu)$ is attained at $\mu = \frac{a-\epsilon^H}{2a}$. Therefore, if $f(\frac{a-\epsilon^H}{2a}) \leq g(\frac{a-\epsilon^H}{2a})$, i.e., if $N(a-\epsilon^H)^2 \leq 3a^2 + (\epsilon^H)^2$, then $|I|$ is maximized at $\mu = \frac{a-\epsilon^H}{2a}$. Meanwhile, if $f(\frac{a-\epsilon^H}{2a}) > g(\frac{a-\epsilon^H}{2a})$, then $|I|$ is maximized at the smaller solution of the quadratic equation, $f(\mu) = g(\mu)$, which is given by $\frac{aN-\epsilon^H(N-1)-4\sqrt{a^2(N-1)}}{2(N-1)a}$, because $g(\mu)$ is decreasing in $(0, \frac{a-\epsilon^H}{a})$. $\square$

In either case of proposition 4, it is implied that when credit constraints are very severe or very weak, the international economy is not so unstable, in the sense that the possible amplitude of λ^i is small. However, when credit constraints are at an intermediate level, the international economy is very unstable. The case of two countries provides us with a simple illustration for proposition 4. In the two countries, $\lambda_H = \mu(a(1-\mu) - \epsilon^H)$ and thus $|I| = 2\mu(a(1-\mu) - \epsilon^H)$$=a\mu(\mu - \frac{\epsilon^H-a}{a})$. We note that $|I|$ takes its maximum at $\mu = \frac{a-\epsilon^H}{2a}$.

4 Discussion

4.1 When do sunspots matter?

We have found that when μ is sufficiently close to one and thus the international financial market is perfect, sunspots do not matter, implying that ϵ and λ^i $(i = 1, ..., N)$ are constantly zero. In this case, accordingly, we obtain only a perfect foresight equilibrium. We have also found that when $\mu = 0$, sunspots do not matter. In this case, no agents lend from or deposit financial resources with the financial intermediary, and they have to create consumption goods on their own.

Another interesting case is the one in which a country is a closed economy and the representative financial intermediary is a domestic company. In this case, we have $G(r^{ie}) = \mu$, which means that $\lambda^i = 0$ a.e. and r^{ie} is a deterministic variable. Therefore, in the case of a closed economy, there is no instability in the aggregate output or consumption. However, we should note that the sentiment of the financial intermediary is still affected by sunspot events and thus ϵ could be a random variable. This implies that as long as the financial market is imperfect, a distribution problem of output remains. In other words, sunspots matter to inequality within a country, while they do not matter to the aggregate output or to the aggregate consumption.

4.2 Social Planner *within* a Country

In this subsection, we consider ex-ante and ex-post *constrained* optimalities *within* a country. Suppose that a benevolent social planner within a country i can only choose r^{ie}, namely, he/she cannot command any transactions in the financial market or identify the most capable agents in his/her country. The social planner assigns an equal weight to the utility of each individual and is interested in maximization of the aggregate utility in his/her country, which is given by $\int_0^a c^i dG(\phi) = \frac{F(r^{ie})}{1-\mu} w + r \frac{G(r^{ie})-\mu}{1-\mu} w$.

First, we consider the ex-ante optimality. Suppose that the social planner within a country solves the maximization problem such that:

$$\max_{r^{ie}} E[F(r^{ie}) + r(G(r^{ie}) - \mu)].$$

Then, the solution is given by $E(r^{ie}) = E(r)$.

While the solution $E(r^{ie}) = E(r)$ has been obtained because the heterogeneous agents are uniformly distributed, it is consistent with the assumption of the expectation formation of the future interest rate in the main text. However, we should note that the ex-post optimality cannot be guaranteed once ϵ is fulfilled. If the social planner knew how to achieve ϵ, the ex-post optimal solution would be obtained, which is given by $\lambda^i = \epsilon$. Of course, this is a case of perfect foresight. In our model, agents cannot know the sentiment of the financial intermediary when they make a decision on investment, although they might know the distribution of ϵ.

In the usual macroeconomic model, the formation of rational expectations is homogeneous, implying that $\lambda^1 = \lambda^2 = ... = \lambda^N = 0$ and thus $r^{ie} = a\mu$. In other words, in the usual macroeconomic model, we assume that $r^{ie} = E(r)$. This expectation formation is a subset of our expectation formations and generically yields an ex-post suboptimulity. While the expectation formations associated with $E(r^{ie}) = E(r)$ also yield an ex-post suboptimulity, these expectation formations are rational because individuals do not make systematic errors.

By contrast, in the case in which the financial market is perfect, the optimality before sunspot events coincides with the one after sunspot events, because it holds that $\lambda^i = \epsilon = 0$. Therefore, the expectation of the future interest rate is independent of a country-specific disturbance.

4.3 Social Planner in the World

Suppose that a benevolent social planner can choose every λ^i or equivalently every r^{ie} subject to $\sum_{i=1}^{N} \lambda^i = 0$. As in the previous case, however, he/she cannot command any transactions in the financial market or command production of each individual in the world.

A benevolent social planner assigns an equal weight to each individual in the world and maximizes the aggregate utility:

$$\sum_{i=1}^{N} \frac{F(r^{ie})}{1-\mu} w,$$

subject to $\sum_{i=1}^{N} \lambda^i = 0$. We can easily obtain the solution for this problem, which is given by $\lambda^1 = \lambda^2 = ... = \lambda^N = 0$. This solution is intuitive, namely, because all countries are symmetrical, that is, all the psychological disturbances should be equal to zero for the constrained optimality of the world economy.

We should note that this maximization problem is independent of the sentiment of the financial intermediary. Therefore, in the constrained optimality, the social planner does not care about the distribution problem of output. This is because each individual is risk-neutral with respect to consumption. If the utility function is strictly concave, the constrained optimality is subject to the sentiment of the financial intermediary. In this case, by comparing the marginal utilities among individuals, we hypothesize that some positive ϵ will produce the constrained optimality. This is because ϵ plays a role as a tax rate on the income of rich investors and a subsidy rate on the income of poor savers. If the utility of each individual is strictly concave, then the greater equality among individuals will result in the greater aggregate utility in the world.

5 Concluding Remarks

In the era of financial globalization, economic booms and busts should be considered from the perspective of capital movement. This is because capital inflow and outflow often significantly determine the economic situation of a country, as evident by the many financial crises in 20th and 21st centuries.

In this paper, we have demonstrated that if the international financial market is imperfect, then an economic boom backed by capital inflow will be fragile given the social psychology in the international financial market and the sentiment of the representative financial intermediary. This is because if the international financial market is imperfect, there are infinitely many world interest rates that can support the equilibrium allocation of economic resources and because agents' rational expectations of the future interest rate can waver. Depending upon the interaction among country-specific expectations, some countries experience capital inflow followed by an economic boom, whereas other countries face capital outflow followed by an economic downturn, although they are completely symmetrical before sunspot events.

Our model can be extended to an overlapping generations model. By doing so, we can engage in more intricate discussions about international business fluctuations caused by sunspot events. The reason why we have investigated a simple two-period model in this paper is that we need to avoid the inherent suboptimality of an overlapping generations model. Otherwise, although sunspots do matter in the international economy, we cannot clarify whether the instability due to sunspots comes from the suboptimality of an overlapping generations model or from financial market imperfections. Now that we have understood that sunspots do matter in the international economy because of financial market imperfections, we can proceed to modeling with overlapping generations. This is a topic for future research.

Appendix

Microfoundation for credit constraints

We extend a microfoundation for credit constraints developed by Antrás and Caballero (2009) to the one that is applicable to our economy. To establish the microfoundation, we need to consider a participation constraint of the financial intermediary and incentive compatibility constraints of borrowers such that they do not default.

We impose two assumptions on the behavior of borrowers (entrepreneurs). First, suppose that at the end of the first period, any borrower can back out of his/her investment project at no cost before he/she starts to produce consumption goods but after investment has occurred, taking a part of his/her investment $(1-\mu)(w-b^i)$ where $0<\mu<1$ and not repaying his/her obligation to the financial intermediary. In this case, he/she will produce consumption goods on a deserted island. Second, after the second sunspot, if a borrower would like to default, i.e., does not repay the financial intermediary, he/she can take a part of his/her production $(1-\mu)\phi(w-b^i)$ and incur a cost $-crb^i>0$ where $1-\mu\leq c\leq 1$. One can imagine that the cost has to be paid to a person in an illegal business who helps the borrower walk away.[10]

If a borrower walks away at the end of the first period, then the financial intermediary can take back the amount of the remainder of the investment, $\mu(w-b^i)$. We assume that the financial intermediary can lend the remainder of the investment in the financial market again. Therefore, when the financial intermediary makes a financial contract with a borrower, it faces a participation constraint such that:

$$E(r)\mu(w-b^i)\geq -E(r)b^i,$$

or equivalently[11]

$$b^i\geq -\frac{\mu}{1-\mu}w. \tag{14}$$

[10] We note that if the borrower takes all his/her output ($\mu=0$), the cost is equal to his/her total obligation.

[11] In equilibrium, we note that $E(r)=a\mu>0$ unless $\mu\neq 0$.

In contrast, the incentive compatibility constraint for a borrower not to back out of his/her project at the end of first period is given by:

$$\phi(w - b^i) + r^{ie} b^i \geq \phi(1 - \mu)(w - b^i). \tag{15}$$

If $r^{ie} - \mu\phi \leq 0$ for any realization of r^{ie}, then this inequality always holds. Therefore, we focus on the case in which $r^{ie} - \mu\phi > 0$ for some realization of r^{ie}. In this case, inequality (15) is rewritten as:

$$b^i \geq -\frac{\mu}{(r^{ie}/\phi) - \mu} w. \tag{16}$$

Meanwhile, the incentive compatibility constraint such that a borrower does not walk away after the second sunspot is given by:

$$\phi(w - b^i) + r b^i \geq \phi(1 - \mu)(w - b^i) + c r b^i. \tag{17}$$

If it follows that $(1 - c)r - \phi\mu \leq 0$ for any realization of r, then this inequality always holds. Thus, we focus on the case in which $(1 - c)r - \phi\mu > 0$ for some realization of r. Then, inequality (17) is rewritten as:

$$b^i \geq -\frac{\mu}{(1 - c)(r/\phi) - \mu} w. \tag{18}$$

In what follows, we will demonstrate that the participation constraint (14) is a sufficient condition for the incentive compatible constraints (16) and (18), i.e., inequalities (16) and (18) are redundant if we have the participation constraint (14).

In equilibrium, because $r^{ie}/\phi \leq 1$, it follows that $-\frac{\mu}{(r^{ie}/\phi)-\mu} \leq -\frac{\mu}{1-\mu}$, implying that inequality (16) is redundant. In contrast, it follows that $\frac{(1-c)r}{\phi} \leq \frac{\mu r}{\phi} \leq \frac{r^{ie}}{\phi} \leq 1$. The second inequality follows from lemma 2. Thus, we have $-\frac{\mu}{(1-c)(r/\phi)-\mu} \leq -\frac{\mu}{1-\mu}$, and inequality (18) is redundant.

To summarize, if the financial intermediary imposes a credit constraint $b^i \geq -\frac{\mu}{1-\mu} w$, which is the participation constraint of the financial intermediary, borrowers never default. By letting $\frac{\mu}{1-\mu} := \eta$, we obtain a credit constraint $b^i \geq -\eta w$ in the main text.

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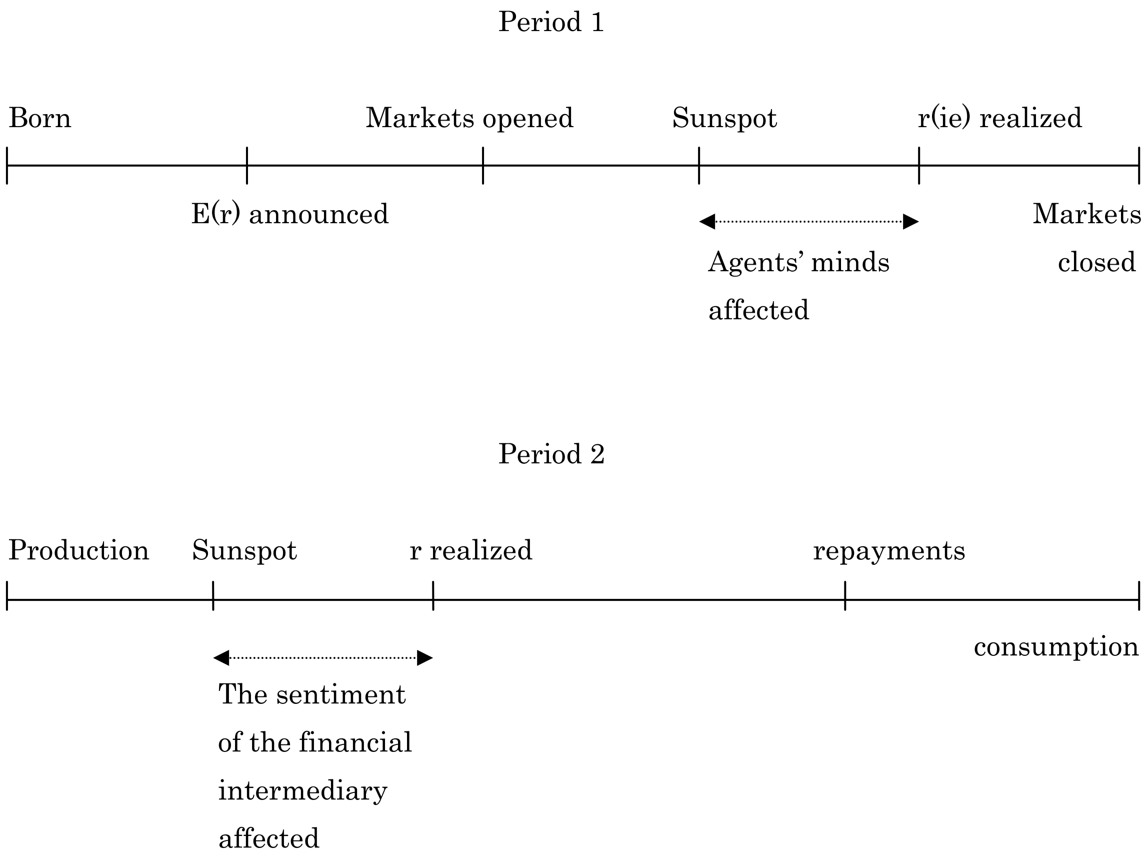
Period 1
Born
Markets opened
Sunspot
r(ie) realized
E(r) announced
Agents' minds affected
Markets closed
Period 2
Production
Sunspot
r realized
repayments
consumption
The sentiment of the financial intermediary affected

Figure 1

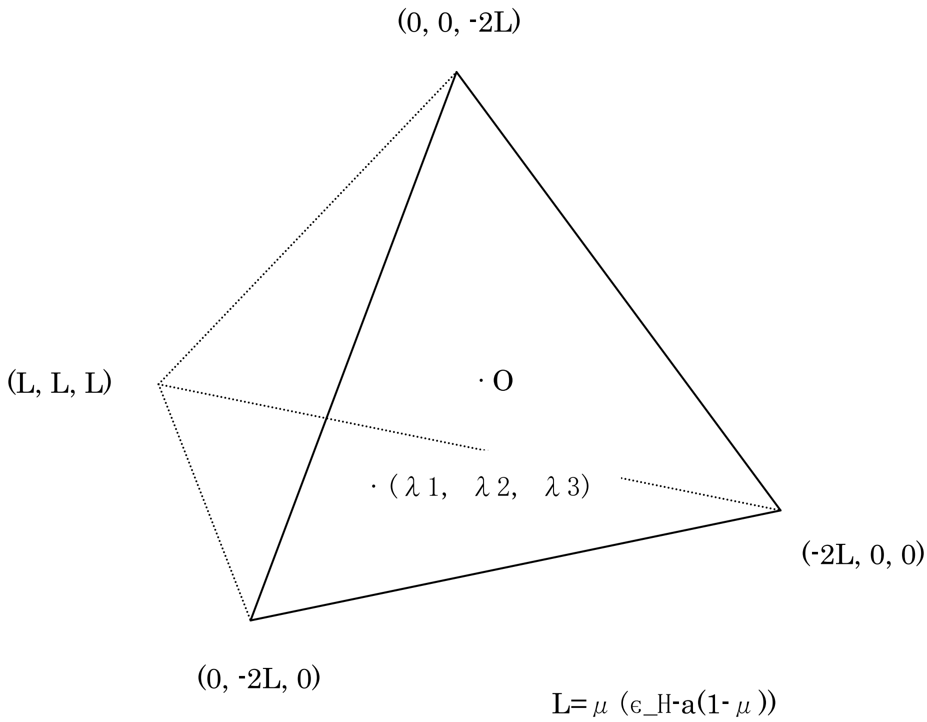

Figure 2