Original Article

Sovereign wealth funds – Investment strategies and financial distress

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ABSTRACT This article discusses the recent developments with regard to sovereign wealth funds (SWFs) and presents a simple model that illustrates their potential impact on global financial stability during periods of market distress. The model incorporates key institutional features of SWFs such as investment strategies, size and disclosure standards that could have a bearing on how shocks are transmitted across financial markets. The model suggests an asymmetric impact of SWFs during financial turmoil and booms, and provides an analytical framework to inform policy discussion with regard to the governance of SWFs.

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INTRODUCTION

Sovereign wealth funds (SWFs) are generally defined as investment funds owned and managed by national governments.¹ SWFs are not a new phenomenon, but, as many emerging markets and commodities-exporting countries have accumulated large stocks of foreign assets, effective wealth management has increasingly

become an important public sector responsibility. Accordingly, the number of SWFs has been rising and assets under management have increased by more than half in the last decade, thereby exceeding assets managed by hedge funds and accounting for between one-fourth and one-third of all foreign assets held by sovereigns. SWFs have become increasingly

important not only within their own countries, but also in the global financial system.

Against this backdrop and that of the recent financial turmoil, officials from recipient countries have noted that SWFs may pose additional risks to the stability of financial markets, as the role of governments in the global financial system has expanded while the investment strategy of SWFs may respond to political objectives. On the other hand, SWFs have been perceived as offering economic benefits to the global financial system by allowing greater diversification and risk-sharing than the reserve management practices of central banks. It is not surprising, therefore, that public and private leaders in both SWF sponsor countries and recipient countries recognized that the international system would benefit from enhanced clarity regarding the principles and practices followed by both sides. In this regard, SWFs have recently formed an International Working Group (IWG) under the auspices of the International Monetary Fund (IMF).

The issue of whether SWFs are a source of additional risks or a stabilizing force, particularly at times of financial distress, has gained momentum, but little analytical work is available. This article develops a framework that incorporates the investment strategies of SWFs and other market participants and their reactions to shocks, allowing for a discussion of how the interplay among market participants potentially affects the stability of the international financial system. It also provides insights into policy discussion on the governance of SWFs, and highlights areas for future empirical work.

This article is organized as follows. It starts by reviewing recent developments, and pointing out the rapid growth in SWFs' activities, the incentive for risk-sharing and the limited disclosure standards of SWFs.

The section after that presents the model framework, and the penultimate section draws some policy implications and highlights areas for future empirical work. The final section concludes.

BACKGROUND

The number and size of SWFs have risen remarkably in the past decade, and are expected to grow further (Figure 1). The number of SWFs has doubled during the last decade, and, of the top 10 largest SWFs, nearly half were established after 2000. Assets under management, which are currently about US\$3 trillion above those managed by hedge funds (\$ 1.9 trillion) and private equity funds, are estimated to reach \$5 trillion by 2010, and surge to \$10 trillion by 2015.²⁻⁴ This estimated growth is much larger than for most other institutional investors such as pension funds or mutual funds.

SWFs have mostly been established in emerging markets and developing countries in recent years (Table 1), responding to a period of buoyant oil and commodities prices and strong economic growth and capital inflows.⁵⁻⁷ These countries have accumulated a large amount of foreign exchange reserves and, against a backdrop of low money markets returns, have found it increasingly compelling to establish alternative investment vehicles that could broaden sovereign portfolio allocations to other major asset classes. In addition to investing their foreign exchange reserves in higher-return assets, SWFs have also been used to hedge against shocks in the commodity- and export-oriented sectors by holding assets whose returns are inversely correlated with the country's primary risk exposure.^{8,9} Over 60 per cent of assets under management by sovereigns are concentrated in

Figure 1: Recent developments of sovereign wealth funds.

Source: IMF, McKinsey Global Institute, Morgan Stanley, various websites, and authors' estimates.

oil- and commodity-related SWFs.¹⁰ Moreover, based on public information, most SWFs adopt diversified investment strategies covering major asset class, including equities, fixed-income instruments (and in some cases, real estates and private equity) and geographic areas (Table 2).

SWFs have been criticized for their perceived weak disclosure requirements. Truman¹¹ and Linaburg and Maduell¹² noted that most SWFs in emerging markets rank poorly in terms of disclosing investment strategies and governance. In contrast, Norway, Australia and Korea have ranked above 9 out of 10 in terms of disclosure in key areas like management, external managers and objectives. We classify the disclosure in terms of a few key areas, including whether the SWFs have indicated their history and objectives, published audited annual reports and disclosed their portfolio allocation (Table 3). We find that the largest SWFs from the emerging markets do not generally disclose adequately relative to their counterparts in the developed countries.

Although governance issues are usually considered microeconomic in nature, it can

be argued that they could have significant macroeconomic effects and undermine the stability of the international financial system. Previous IMF staff research suggests that the pattern of global capital flows could be affected by an increased participation of SWFs in international financial markets.^{13–15} For instance, a shift away from the asset classes in which foreign exchange reserves have been traditionally held could impact asset prices and cross-border financial flows, while actual or rumored transactions may affect valuations in particular sectors and result in herding behavior, adding to volatility. Given the size of their portfolios, SWFs may potentially cause market disturbance and destabilize the global financial system. Such effects could be especially pronounced in shallower markets and require recipient countries to strengthen their policy framework and design appropriate policies.

Given data limitation, an extensive empirical analysis is not a viable approach. Event studies analyzing the role of SWFs are subject to sample bias, as they would include only publicly disclosed SWFs' transactions. Presented below is

Table 1: List of sovereign wealth funds across countries as of June 2008

<i>Country^a</i>	<i>Names of SWFs</i>	<i>Type</i>	<i>Year established</i>	<i>US (billion)</i>	<i>Geographical coverage</i>	<i>Portfolio allocation</i>
Algeria	Revenue Regulation Fund	Oil	2000	47	—	—
Angola	Reserve Fund for Oil	Oil	2007	0	—	—
Australia	Australian Future Fund	Non-commodity	2004	59	Mainly local	Only 18% in international equities
Azerbaijan	State Oil Fund of the Republic of Azerbaijan	Oil	1999	5	Global asset allocation	Equities and fixed-income
Bahrain	Bahrain Mumtalakat Holding Company	Oil	2006	10	Regional	Equities and corporates
Botswana	Pula Fund	Diamond	1966	7	—	Equities and fixed-income
Brazil ^b	TBA	TBA	2008	8–10*	Mainly local	Equities and corporates
Brunei	Brunei Investment Authority	Oil	1983	30	Global asset allocation	Major asset class
Canada	General Reserve Fund	Oil	1976	17	Global asset allocation	Major asset class
Chile	Alberta Heritage Savings Trust Fund	Oil	1976	17	Global asset allocation	Major asset class
	Economic and Social Stabilization Fund; Pension Reserve Fund	Copper	1985	16	Stabilization	Fixed-income instruments
China	State Foreign Exchange Investment Corporation/China Investment Corporation	Non-commodity	2007	200–311	Global asset allocation	Unknown; major asset class
East Timor	Timor-Leste Petroleum Fund	Oil	2005	3	Global asset allocation	Major asset class
India ^b	TBA	TBA	TBA	5*	—	—
Iran	Oil Stabilisation Fund	Oil	1999	13	Global asset allocation	Equities and fixed-income
Ireland	National Pensions Reserve Fund	Non-commodity	2001	31	Global asset allocation	Equities and fixed-income
Kazakhstan	Kazakhstan National Fund	Oil	2000	22	—	—
Kiribati	Revenue Equalization Reserve Fund	Phosphates	1956	0	—	—

Table 1 *continued*

<i>Country^a</i>	<i>Names of SWFs</i>	<i>Type</i>	<i>Year established</i>	<i>US (billion)</i>	<i>Geographical coverage</i>	<i>Portfolio allocation</i>
Korea	Korea Investment Corporation	Exports	2005	30	Global asset allocation	Major asset class
Kuwait	Kuwait Investment Authority; General Reserve Fund; Future Generations Fund	Oil	1953	250	Global asset allocation	Major asset class
Libya	Libyan Arab Foreign Investment Company	Oil	1981	50	Regional	—
Malaysia	Khazanah Nasional	Non-commodity	1993	25.7	Local	Equities and corporates
Mauritania	National Fund for Hydrocarbon Reserves	Oil and gas	2006	0	—	—
New Zealand	New Zealand Superannuation Fund	Non-commodity	2003	14	Global asset allocation	Major asset class
Nigeria	Excess Crude Account	Oil	2004	11	—	—
Norway	Government Pension Fund – Global	Oil	1990	397	Global asset allocation	40% equities; 60% global fixed income
Oman	State General Reserve Fund	Oil	1980	2	—	—
Qatar	Qatar Investment Authority	Oil	2000	60	Global asset allocation	Major asset class
Russia	Oil Stabilization Fund/National Welfare Fund*	Oil	2004	163	—	96% in global fixed-income instruments
Saudi Arabia	Public Investment Fund	Oil	2008	5	Global asset allocation	—
Saudi Arabia	SAMA Foreign Holdings	Oil	NA	300	Global asset allocation	Major asset class
Singapore	Government Investment Corporation; Temasek Holdings	Non-commodity	1974	159	Global asset allocation	Major asset class
Taiwan, POC	National Stabilisation Fund	Non-commodity	2000	15	Local	Equities and corporates
		Oil	1976	875	Global asset allocation	Major asset class

Table 1 *continued*

<i>Country^a</i>	<i>Names of SWFs</i>	<i>Type</i>	<i>Year established</i>	<i>US (billion)</i>	<i>Geographical coverage</i>	<i>Portfolio allocation</i>
United Arab Emirates	Abu Dhabi Investment Authority/Abu Dhabi Investment Council					
United States (Alaska)	Alaska Permanent Reserve Fund	Oil	1976	40	State-owned	All major asset class
United States (New Mexico)	New Mexico State Investment Office Trust	Non-commodity	1958	16	—	—
United States (Wyoming)	Permanent Wyoming Mineral Trust Fund	Commodity	1974	4	—	—
Venezuela	FIEM – Macroeconomic Stabilization Fund	Oil	1999	1	—	—
Vietnam	State Capital Investment Corporation	Non-commodity	2006	2	Local	—
Total ^c				2977		
of which: commodity-related funds				2024		

^aChad, Ecuador, Equatorial Guinea, Gabon, Mexico, Sudan, Trinidad and Tobago, and Uganda also have official funds established.

^bFigures based on news report.

^cSome funds not listed also contribute to the total sum. Figures from Sovereign Wealth Fund Institute as of 12 June 2008.

Source: Sovereign Wealth Fund Institute, IMF, *Financial Times*, Linaburg and Maduell¹² and various websites.

NA=Not available.

*=Preliminary.

Table 2: Risk-sharing incentive of sovereign wealth funds

Country	Type	Year established	US (billion)	Risk-sharing/ diversification	Geographical coverage
Australia	Non-commodity	2004	59	—	Mainly local
China	Non-commodity	2007	200–311	Y	Global asset allocation
Korea	Non-commodity	2005	30	—	Global asset allocation
Kuwait	Oil	1953	250	Y	Global asset allocation
Norway	Oil	1990	397	—	Global asset allocation
Qatar	Oil	2000	60	Y	Global asset allocation
Russia	Oil	2004	163	Y	—
Saudi Arabia	Oil	NA/2008	300	Y	Global asset allocation
Singapore	Non-commodity	1974	159	Y	Global asset allocation
United Arab Emirates	Oil	1976	875	Y	Global asset allocation

Source: Sovereign Wealth Fund Institute, IMF, *Financial Times* and various websites.

NA=Not available.

an analytical framework that incorporates the investment objectives and behavior of SWFs and other institutions.

THE ANALYTICAL FRAMEWORK

The framework builds on the literature on the transmission mechanism of financial distress, as discussed in Morris and Shin^{16,17} and Campos,¹⁸ by explicitly incorporating SWFs as a specific class of investors. It illustrates how the interplay among diverse institutions impacts the likelihood of shocks turning into crises and the transmission mechanism therein.

The existing literature on self-fulfilling financial crises provides an analytical framework in which the impact of shocks to fundamentals on financial stability takes account of market participants' rational reaction to the expectation that other participants would run for the exit when faced with those shocks. However, the framework distinguishes neither among different classes of

market participants in terms of the relative impact of their actions in triggering a financial crisis nor the potentially larger joint impact of such actions.

This article explores a novel transmission mechanism by explicitly incorporating the investment objectives and behavior of SWFs. The key characteristics of the proposed framework are:

- *Uncertainty.* At $t = 0$, investors are uncertain as to which state of the economy, $s \in [\underline{s}, \bar{s}]$, will prevail at time $t = 1$, where s has density function $p(s)$. Total wealth is identified by an aggregate endowment $e(s)$, which is increasing with s . It is equal to $\sum_i e_i(s)L_i$, where $e_i(s)$ identifies each investor's endowment and L_i , which is equal to or greater than 1, identifies each investor's leverage.
- *Market participants.* Investors (i) have different degrees of risk aversion and leverage. SWFs are assumed to be risk averse ($\gamma_i > 0$) and not leveraged ($\gamma_{SWF} > 0$ and $L_{SWF} = 1$).

Table 3: Disclosure indicators among the 10 largest SWFs

Country	Transparency ratings ^a	Disclosure indicators							Website/ Contact
		History	Audited annual reports	Portfolio holdings/ Asset class	Management	Policy and governance guidelines	Strategy and objective	External managers	
Norway	10	Y	Y	Y	Y	Y	Y	Y	Y
Australia	9	Y	Y	Y	Y	Y	Y	Y	Y
Korea	9	Y	Y	Y	Y	Y	Y	Y	Y
Ireland	7	—	Y	Y	—	—	Y	Y	Y
Singapore	6–7	Y	—	—	Y	Y	Y	—	Y
Kuwait	6	Y	—	—	Y	—	Y	—	Y
Russia	5	—	—	—	—	—	—	—	Y
Saudi Arabia	NA	—	—	—	—	—	Y	—	—
Saudi Arabia	4	Y	—	—	Y	—	—	—	—
United Arab Emirates	3	Y	Y	—	—	—	Y	—	Y
Chile	3	Y	—	—	—	—	Y	—	—
China	2	Y	—	—	Y	—	—	—	Y
Iran	2	—	—	—	—	—	—	—	—
Qatar	1	—	—	—	—	—	Y	—	Y

^aLinaburg and Maduell¹².Source: Sovereign Wealth Fund Institute, IMF, *Financial Times* and various websites.

NA=Not available.

Heterogeneity with regard to risk aversion and leverage drives portfolio allocation at $t=0$ and assets liquidation at $t=1$. Market participants maximize the same standard Constant Relative Risk Aversion (CRRA) utility function:

$$U(s) = E_s \left(\frac{c(s)^{1-\gamma_i}}{1-\gamma_i} \right) \quad (1)$$

- *Time dimension.* Decisions are taken at three points in time, $t = \{0, 1, 2\}$. At time $t=0$, market participants (including SWFs) trade contingent claims (of same type) to hedge against risk and to build their portfolios. At time $t=1$, uncertainty is realized and the state of the economy is observed by all market participants. At this point, participants decide how much of their asset holdings to liquidate subject to their expectation of a financial crisis and of other investors' liquidation strategies. At time $t=2$, market participants receive the return on their portfolios.
- *Payoffs.* Proceeds from liquidated assets at $t=1$ earn a riskless return D . Returns on

of the economy s at $t=1$, and (ii) investors' expectations, at $t=1$, of a crisis in $t=2$, which, in turn, depends on the liquidity of financial markets at $t=1$. The liquidity of financial markets at $t=2$ is the result of each investor's decision to liquidate after observing the state of economy at $t=1$, $\Omega(s, \Theta_s)$.

Accordingly, liquidity (Θ_s) is assumed to be normally distributed with $\sim N(\mu(s), \sigma^2)$. A financial crisis at $t=2$ occurs only if liquidations by investors bring liquidity to below a certain level, that is $\Omega(s) \geq \Theta_s^*$, where the threshold Θ_s^* will be discussed below.

- *Information structure.* At $t=0$ investors know only the distribution of Θ_s . At $t=1$, investors receive private information γ . It is assumed that $\gamma = \Theta_s + \varepsilon$, where ε is a white noise with zero mean and variance σ_ε^2 . Individual investors then update their expectation about the probability of a crisis ($1-\delta_i$); δ_i represents the individual investor's belief that a financial crisis would not occur.

The above can be formally described as:

$$\begin{aligned} & \max_{\alpha(s, \theta)} E_s \left(\frac{c(s)^{1-\gamma_i}}{1-\gamma_i} \right) \\ & = \max_{\alpha(s, \delta)} E_s \left\{ \frac{1}{1-\gamma_i} \left\{ \left[\delta_i (R\alpha(s, \gamma_i, L_i) - (R-D)\omega_i(s, \gamma_i, L_i, \delta_i)) \right]^{1-\gamma} + \right. \right. \\ & \quad \left. \left. \left[(1-\delta_i) (R_c\alpha(s, \gamma_i, L_i) - (D-R_c)\omega_i(s, \gamma_i, L_i, \delta_i)) \right]^{1-\gamma} \right| \Theta_s^* \right\} \right\} \quad (2) \end{aligned}$$

holdings that are not liquidated vary. If a financial crisis occurs at $t=2$, asset prices fall sharply and earn a return R lower than D . If, instead, a financial crisis does not occur at $t=2$, investors earn a return R higher than D .

- *Financial crisis trigger.* The size of holdings that are liquidated at $t=1$ depends on (i) the state

subject to the resource constraint:

$$\begin{aligned} E_s[q(s)\alpha(s, \gamma)] & \leq E_s[q(s)e_i(s)] \\ \omega_i(s, \delta_i, L_i) & = \alpha_i(s) \quad \text{if } \alpha_i(s) < L_i \end{aligned}$$

where $q(s)$ is the price of state-contingent claims.

The model can be solved using backward induction, starting at $t=1$. Individual investors choose the size of holdings to be liquidated

$(\omega(s, \delta_i, \gamma_i, L_i))$ (or $\omega(s, \delta_i)$, as risk aversion and leverage are fixed parameters), taking the state of the economy (s) as given. The optimal size of liquidation is the solution to the following maximization problem:

$$\max_{\omega_i(s)} \left(\frac{c_i(s)^{1-\gamma_i}}{1-\gamma_i} |s, \delta_i \right) = \max_{\omega(s, \delta_i)} \frac{1}{1-\gamma_i} \left\{ [\delta_i(R\alpha_i(s) - (R-D)\omega(s, \delta_i))]^{1-\gamma_i} + [(1-\delta_i)(R_c\alpha_i(s) - (D-R_c)\omega(s, \delta_i))]^{1-\gamma_i} \right\} \quad (3)$$

given investors' holdings $\alpha_i(s; \gamma_i, L_i)$ (or $\alpha_i(s)$), and individual investors' expectations, δ_i , that a financial crisis will not occur; both are known before choosing the size of liquidation). Investors consume the returns from the assets, which is expressed as:

$$\begin{aligned} &\omega(s, \delta_i) \cdot D + \delta_i \cdot R \cdot [\alpha_i(s) - \omega(s, \delta_i)] \\ &+ (1 - \delta_i) \cdot R_c \cdot [\alpha_i(s) - \omega(s, \delta_i)] \end{aligned} \quad (4)$$

Proposition 1: The optimal size of liquidation $\omega_i^*(s, \delta_i)$ satisfies the following conditions:

- (i) $0 < \underline{\delta} < \bar{\delta} < 1$;
- (ii) $\lambda(s, \delta_i) = 1$ iff $\delta_i \in [0, \underline{\delta}]$
- (iii) $\lambda(s, \delta_i) = 0$ iff $\delta_i \in [\bar{\delta}, 1]$
- (iv) $\lambda(s, \delta)$ is decreasing in δ_i and increasing in γ_i in the range $\delta \in [\underline{\delta}, \bar{\delta}]$
- (v) $\omega(s, \delta_i)$ is increasing in L_i . (5)

Proof:

See Appendix A, where $\lambda(s, \delta_i) = \omega(s, \delta_i) / \alpha_i(s)$ is the fraction of assets that are liquidated. Under the first three conditions, $\lambda(s, \delta_i)$ is independent of investors' expectations of a future financial crisis. These conditions define upper and lower bounds on investors' expectations of a future financial crisis according to which investors would either liquidate their whole portfolio or

not liquidate at all, regardless of risk aversion and leverage. These bounds correspond to the 'very good' and 'very bad' states of the economy, respectively.

The last condition establishes that $\lambda(s, \delta_i)$ is weakly increasing with risk aversion, the riskless rate of return and investors' expectations of a future financial crisis. For instance, investors with higher risk aversion (for example SWFs) would tend to liquidate more relative to other investors, given the same expectations and holdings.

Investors' expectations of a future financial crisis, δ_i , can be defined by a conditional cumulative density function (CDF):

$$\delta_i = 1 - G(\Theta_s^* | \gamma_i, s)$$

where

$$G(\Theta_s^* | \gamma_i, s) \equiv \Pr\{\Theta_s < \Theta_s^* | \gamma_i, s\}' \quad (6)$$

with δ_i depending on the private signal (γ_i) and the state of the economy (s).¹⁹ The conditional CDF $G(\cdot)$ measures the probability for the individual investor that the liquidity of the financial markets lies below a threshold Θ_s^* , that is, a crisis occurs if and only if $\Theta_s < \Theta_s^*$.

The aggregate size of liquidation – that is, the sum of all liquidations by individual investors can be expressed as:

$$\begin{aligned} \Omega(s, \Theta_s^*) &\equiv \sum_i \omega(s, \delta_i) \\ &= \sum_i \alpha_i(s) \int \lambda(s, \delta_i) dF(\delta_i | s, \Theta, \Theta_s^*) \end{aligned} \quad (7)$$

The first term $\alpha_i(s)$ indicates the share of assets held by individual investors, whereas the second represents the individual liquidation taking into account individual expectations of a crisis, given the state of the economy.

Proof:

See Appendix B.

The fact that investors' decisions about how much of their portfolio to liquidate at $t = 1$ depends, *inter alia*, on their private signal (y_i) introduces endogeneity in the model. As the probability of a crisis depends on the aggregate size of liquidation, which, in turn, depends on individual investors' decisions, the latter and the probability of a crisis need to be determined simultaneously in equilibrium.^{20–22} Therefore, the distribution of beliefs is an equilibrium object to be endogenously determined. Morris and Shin,^{16,17} Campos,¹⁸ and Hellwig *et al*²¹ show that the equilibrium exists and is unique.

Proposition 2: The aggregate size of liquidation will vary according to the state of the economy, risk aversion and the liquidity of the financial markets:

$$\frac{\partial \Omega(s, \Theta_s^*)}{\partial \mu} < 0; \quad \frac{\partial \Omega(s, \Theta_s^*)}{\partial \gamma_i} > 0; \quad \frac{\partial \Omega(s, \Theta_s^*)}{\partial L_i} > 0 \quad (8)$$

Higher expected liquidity implies lower likelihood of a financial crisis and, hence, smaller size of aggregate liquidation. An increase in risk aversion triggers a larger aggregate liquidation, as investors tend to shy away from assets with riskier returns (see Appendix C).

The aggregate size of liquidation impinges upon the probability of a financial crisis at $t = 2$,

which, in turn, depends on the liquidity threshold Θ_s^* :

$$\begin{aligned} \phi(s) &= \Pr(\{\text{crisis occurs in a given state } s\}) \\ &= \Phi\left(\frac{\Theta_s^* - \mu(s)}{\sigma}\right) \end{aligned} \quad (9)$$

The higher the threshold, the higher the probability of a financial crisis, where the threshold is the amount of liquidity necessary to match aggregate liquidation determined at $t = 1$.

Given the solution to the maximization problem at $t = 1$, at $t = 0$ investors choose their portfolio allocation, $\alpha_{i,s}$, given their risk aversion and the expected probability of a financial crisis, which is the same for every investor, maximizing the problem as shown in (2). The more risk averse investors are, the larger the share of assets with relatively higher payoffs in the case of a negative shock to the economy (low s) in their portfolio. This entails that, at $t = 1$, and in the case of a negative shock, the market value of the share of total wealth held by risk-averse investors increases (see Appendix D).

The model's transmission mechanism can be formulated formally as follows:

$$\phi(s) = \Pr\{\delta \leq \Theta_s^* | s\} = CDF\left(\frac{\Theta_s^* - \mu(s)}{\sigma}\right) \quad (10)$$

which indicates the probability of a financial crisis.

Proposition 3: This probability depends (inversely) on the realization of the state of the economy, through the expected liquidity of the financial market, $\mu(s)$, and the liquidity threshold Θ_s^* (see Appendix E):

$$\begin{aligned} \frac{\partial \phi(s)}{\partial s} &= \left[\frac{\partial \Phi'(s)}{\partial \mu(s)} \cdot \frac{\partial \mu(s)}{\partial s} + \frac{\partial \Phi'(s)}{\partial \Theta_s^*} \cdot \frac{\partial \Theta_s^*}{\partial \mu(s)} \cdot \frac{\partial \mu(s)}{\partial s} \right] \\ &\quad + \frac{\partial \Phi'(s)}{\partial \Theta_s^*} \cdot \frac{\partial \Theta_s^*}{\partial e_t(s)} \cdot \frac{\partial e_t(s)}{\partial s} < 0 \end{aligned} \quad (11)$$

1/ Rounded-rectangular boxes represent realization of variables. Rectangular boxes represent decisions or choices made by the market participants.

Figure 2: Transmission mechanism on the likelihood of a financial crisis.

This model captures the impact of the realization of a shock at $t = 1$ on the expected liquidity of the financial market, $\mu(s)$, at $t = 2$, and, hence on the likelihood of a financial crisis (*basic channel*). A deterioration in the state of the economy, s , *ceteris paribus*, would decrease the expected liquidity of the financial market, and, hence, increase the likelihood of a financial crisis. This model also captures two additional channels through which a shock affects the likelihood of financial crisis (Figure 2):

- The *information channel* captures investors' decision to liquidate on the basis, *ceteris paribus*, of their individual expectations of a financial crisis, δ_i , which depends on the realization of a shock at $t = 1$, coupled with their expectations about liquidation decisions by others. A negative shock would, as in the basic channel, decrease the expected liquidity of the financial market and increase investors'

expectations of a financial crisis. This would directly increase investors' liquidations. In addition, the expectation of larger liquidations by others would further contribute to increasing each investor's liquidations, and, accordingly, the aggregate size of liquidation. The latter, which corresponds to a larger Θ_s^* , would, in turn, imply a higher probability of a financial crisis.

- The *portfolio channel* captures the compounded impact of risk aversion on investors' decisions to liquidate. As shown above, when the economy is hit by a negative shock, the share of total wealth held by risk-averse investors increases. Moreover, as shown in (8), the more risk averse investors are, the larger the share of their portfolio holdings that they would liquidate for any given expectation of a financial crisis. This means that, in the case of a negative shock, the higher the risk aversion, the larger the aggregate size of liquidation, and, hence the higher the

probability of a financial crisis. However, the portfolio channel would not yield a symmetric result in the case of a positive shock because the aggregate size of liquidation would decrease relatively less, as the share of total wealth held by risk-averse investors would be relatively smaller.

- The *leverage channel* captures the multiplicative impact of leveraging on the aggregate size of liquidation. Higher leverage would imply a larger impact on the aggregate size of liquidation because it increases (i) the size of investors' portfolios (when compared with the size of the portfolios in the absence of leverage), and (ii) the share of the portfolio that needs to be liquidated. The larger the aggregate size of liquidation, the higher the probability of a financial crisis.

POLICY IMPLICATIONS

The model offers an analytical framework in which the impact of portfolio allocations by SWFs on the occurrence of a financial crisis can be analyzed. The framework explicitly accounts for several transmission channels through which such impact can be felt and the appropriate policy, including regulatory, responses discussed. Some of these issues are briefly taken up below.

Portfolio allocation and cross-sectional asset holdings

Recognizing heterogeneity when considering SWFs portfolio strategies is important. SWFs in countries at different phases of economic developments may have different investment strategies. For instance, SWFs in oil-exporting countries may invest in asset classes that are very different from countries of SWFs that demand natural resources. A uniform policy for all SWFs on investment strategies may not be applicable.

Policy discussion generally underplays the portfolio allocation strategies of SWFs. Although most discussions rightly recognize their increasing size and diversification motives, the variation of cross-sectional asset holdings in the financial market and correlation of fundamentals with domestic shocks are generally not explicitly considered.²²

Asymmetric role of SWFs in financial markets

The transmission mechanism notes an asymmetric role of SWFs during financial distress and boom. Asset re-allocation by SWFs would raise concerns at times of potential financial distress, although not necessarily during periods of financial boom. Specifically, the size of SWFs becomes relatively important, and sometimes a determining role, in a potential financial distress, given a deterioration of fundamentals. Empirical works on financial stability may need to incorporate this asymmetry.

Disclosure and governance of SWFs

The appropriate disclosure of the investment strategies and governance of SWFs would mitigate information asymmetries, weaken the impact from the information channel, and, hence reduce the likelihood that financial distress escalates into a financial crisis.

Promoting financial stability

From the viewpoint of the global financial system, SWFs can facilitate a more efficient allocation of resources generated by high commodity prices, and favorable balance of payments developments more generally, across countries and enhance market depth and liquidity, including at times of financial stress. SWFs can play a stabilizing role in global financial markets, particularly because most of

them are long-term investors with mainly unleveraged positions.

CONCLUSIONS

This article discusses the recent developments of the SWFs, and illustrates, using a simple model, their role in contributing to financial stability at times of potential financial distress. The model identifies additional transmission mechanisms through which SWFs could impact financial markets, particularly in light of their increasing size, limited disclosure practices and portfolio allocation objectives. The model suggests that SWFs' investment strategies play an asymmetric role during financial distress and boom. By stressing the additional transmission mechanism, this article provides insights to policy guidelines in relation to SWFs' governance, and highlights key areas for empirical works.

REFERENCES AND NOTES

- 1 A special investment fund created or owned by a government to hold assets for long-term purposes; it is typically funded from reserves or other foreign currency sources, including commodity export revenues, and predominantly owns, or has significant ownership of, foreign currency claims on non-residents.
- 2 Jen³ and Farrell and Lund⁴ project that assets under management could exceed official reserves by 2011.
- 3 Jen, S. (2007) How Big Could Sovereign Wealth Funds Be by 2015? Morgan Stanley Research, May 2007.
- 4 Farrell, D. and Lund, S. (2007) The New Power Brokers: How oil, Asia, hedge funds, and private equity are shaping global capital markets, McKinsey Global Institute, October 2007.
- 5 Butt, B., Shivdasani, A., Stendevad, C. and Wyman, A. (2008) Sovereign wealth funds: A growing global force in corporate finance. *Journal of Applied Corporate Finance* 20(1): 73–83.
- 6 Kern, S., Speyer, B., Kaiser, S. and Walter, N. (2007) Sovereign Wealth Funds – State Investments on the Rise. Deutsche Bank Research, September 2007.
- 7 Mitchell, O., Piggott, J. and Kumru, C. (2008) Managing Public Investment Funds: Best Practices and New Challenges. NBER Working Paper No. 14078.
- 8 The Asian and Middle Eastern SWFs have invested large sums of capital in the United States and other developed countries during the second half of 2007. While SWFs are invested broadly throughout Western markets, investments have been particularly concentrated in financial institutions. Following losses stemming from the August 2007 US sub-prime mortgage crisis, many financial institutions sought large investments from foreign SWFs and other large institutional investors. An estimate from Dealogic suggests that SWFs have invested \$37.9 billion in US financial institutions in 2007 (about 63 per cent of the total activity).⁹
- 9 Federal Reserve Bank San Francisco. (2007) Sovereign wealth funds: Stumbling blocks or stepping stones to financial globalization? *Economic Letter* December 2007.
- 10 Some countries, notably China, Brazil and Russia, have also established non-commodity-related SWFs.
- 11 Truman, E. (2007) Sovereign Wealth Funds: The Need for Greater Transparency and Accountability. Peterson Institute for International Economics, Policy Brief, 2007.
- 12 Linaburg and Maduell (2008) Disclosure and transparency ranking of sovereign wealth funds. Sovereign Wealth Fund Institute, www.swfinstitute.org, June 2008.
- 13 International Monetary Fund.^{14–15}
- 14 International Monetary Fund. (2007a) The rise of sovereign wealth funds. *Finance and Development* 44(3): 56–57.
- 15 International Monetary Fund. (2007b) Financial Market Turbulence: Causes, Consequences, and Policies. Global Financial Stability Report, October 2007.
- 16 Morris, S. and Shin, H.S. (1998) Unique equilibrium in a model of self-fulfilling currency attacks. *American Economic Review* 88(3): 587–597.
- 17 Morris, S. and Shin, H.S. (2004) Coordination risk and the price of debt. *European Economic Review* 48(1): 133–153.
- 18 Campos, R. (2007) Risk-sharing and probabilities of bank runs. University of California, Los Angeles (unpublished paper).
- 19 Investors use the private signals to update their expectation of the likelihood of a financial crisis, regardless of their risk aversion, holdings and state of the economy. The properties of Bayesian updating method implies

$$\theta | y \sim N\left(\frac{y\sigma^2 + \mu(s)\sigma_\varepsilon^2}{\sigma^2 + \sigma_\varepsilon^2}, \frac{\sigma^2\sigma_\varepsilon^2}{\sigma^2 + \sigma_\varepsilon^2}\right)$$
 and the CDF has the properties that it is increasing in Θ , but decreasing in γ and $\mu(s)$.
- 20 The inference from the private signals does not depend on risk aversion or asset holdings. As a result, investors receiving same signals will behave in the same way, as shown by Morris and Shin.^{16–17}

- 21 Hellwig, C., Mukherji, A. and Tsyvinski, A. (2006) Self-fulfilling currency crises: The role of interest rates. *American Economic Review* 96: 1769–1787.
- 22 Balding, C. (2008) A portfolio analysis of sovereign wealth funds. University of California, Irvine (unpublished paper).
- 23 In equilibrium, market participants that have the same belief will act identically regardless of their asset position and wealth level at date 1 once the aggregate state is realized, according to the general results from Bayesian updates.

APPENDIX A

The size of liquidation, $\omega(s, \delta_i, \gamma_i, L_i)$ (abbreviated as $\omega(s, \delta_i)$), will be a fraction of the asset holding, $\omega(s, \delta_i) = \lambda(s, \delta_i) \alpha_i(s)$, where $\lambda(s, \delta_i)$ is a fraction between 0 and 1. There exist threshold levels in relation to the withdrawal rule with the following properties.

- (i) $0 < \underline{\delta} < \bar{\delta} < 1$;
- (ii) $\lambda(s, \delta_i) = 1$ iff $\delta_i \in [0, \bar{\delta}]$
- (iii) $\lambda(s, \delta_i) = 0$ iff $\delta_i \in [\bar{\delta}, 1]$
- (iv) $\lambda(s, \delta_i)$ is decreasing in δ_i and increasing in γ_i at the range $\delta_i \in [\underline{\delta}, \bar{\delta}]$
- (v) $\omega(s, \delta_i)$ is increasing in L_i

Proof:

Taking the first derivatives with respect to the size of liquidation $\omega(s, \delta_i)$,

$$\frac{\partial U(.)}{\partial \omega} = -\delta_i [R\alpha(s) - (R - D)\omega(s, \delta_i)]^{-\gamma_i} \times (R - R_d) + (1 - \delta_i) [R_c \alpha(s) + (D - R_c)\omega(s, \delta_i)]^{-\gamma_i} (D - R_c)$$

- (1) If $\omega(s, \delta_i) = \alpha(s)$, it implies $\lambda(s, \delta_i) = 1$, such that the first derivate becomes

$$-\delta_i [D\omega(s, \delta_i)]^{-\gamma_i} (R - D) + (1 - \delta_i) [D\omega(s, \delta_i)]^{-\gamma_i} (D - R_c) > 0$$

$$\delta_i < \bar{\delta} \equiv \frac{(D - R_c)}{(R - R_c)}$$

- (2) If $\omega(s, \delta_i) = 0$, it implies $\lambda(s, \delta_i) = 0$, such that the first derivate becomes

$$-\delta_i' [R\alpha_i(s)]^{-\gamma_i} (R - D) + (1 - \delta_i) [R_c \alpha_i(s)]^{-\gamma_i} (D - R_c) < 0$$

$$\delta_i > \bar{\delta} \equiv \frac{(D - R_c)}{(R - D)(R_c/R)^{\gamma_i} + (D - R_c)}$$

- (3) In case where $0 < \omega(s, \delta_i) < \alpha_i(s)$,

$$\frac{\partial U(.)}{\partial \omega} = -\delta_i [R\alpha_i(s) - (R - D)\omega(s, \delta_i)]^{-\gamma_i} \times (R - D) + (1 - \delta_i) [R_c \alpha_i(s) + (D - R_c)\omega(s, \delta_i)]^{-\gamma_i} (D - R_c) = 0$$

$$\delta_i [R - (R - D)\lambda(s, \delta_i)]^{-\gamma_i} (R - D) - (1 - \delta_i) [R_c + (D - R_c)\lambda(s, \delta_i)]^{-\gamma_i} \times (D - R_c) = 0$$

$$\lambda(s, \delta_i) = \frac{R - R_c A^{1/\gamma_i}}{R - D + (D - R_c) A^{1/\gamma_i}} \quad \text{if } \underline{\delta} < \delta_i < \bar{\delta}$$

$$\text{where } A \equiv \left[\frac{\delta_i}{1 - \delta_i} \cdot \frac{R - D}{D - R_c} \right]$$

$\lambda(s, \delta_i)$ is decreasing with belief δ_i but increasing in γ_i .

$$\frac{\partial \lambda(s, \delta_i)}{\partial \delta_i} = \frac{(R - R_c)A}{(1 - \delta_i)\delta_i[(R - D) + (D - R_c)A]^2 \gamma_i} < 0$$

$$\frac{\partial \lambda(s, \delta_i)}{\partial \gamma_i} = \frac{(R - R_c)A \ln(A^{\gamma_i})}{[(R - D) + (D - R_c)A]^2 \gamma_i^2} > 0$$

- (4) Higher leverage L_i for a given endowment level would imply higher asset holding $\alpha_i(s)$ at $t = 1$. As the size of liquidation is proportional to asset holding, $\omega_i(s, \delta_i)$ is increasing in L_i .

APPENDIX B

The investor's expectation that a financial crisis will *not* occur, δ_i , follows the conditional CDF $\delta_i = 1 - G(\Theta_s^* | \gamma_i, s)$, where $G(\Theta_s^* | \gamma_i, s) \equiv \Pr\{\Theta_s < \Theta_s^* | \gamma_i, s\}$. The conditional CDF ($G(\cdot)$) measures the probability that liquidity of the financial markets below a threshold value Θ_s^* , such that a crisis occur if and only if $\Theta_s < \Theta_s^*$.²³

Proof:

Define γ_i^* to be the solution that satisfies the condition $\delta_i = 1 - G(\Theta_s^* | \gamma_i^*, s)$. The set of

signal (γ_i^*) that is consistent with the threshold Θ_s^* and belief δ_i can be found by inverting the above expression such that

$$\gamma_i^*(\delta_i, \Theta_s^*) = \frac{(\sigma^2 + \sigma_\varepsilon^2)}{\sigma^2} \left(\Theta_s^* - \Phi^{-1}(1 - \delta_i) \times \left(\frac{\sigma^2 \sigma_\varepsilon^2}{\sigma^2 + \sigma_\varepsilon^2} \right)^{-1/2} \right) - \mu(s) \frac{\sigma_\varepsilon^2}{\sigma^2}$$

Substituting into the set of signals that is equal to or lower than γ_i^* accumulated signals, and rearranging

$$\begin{aligned} F(\delta_i | s, \Theta, \Theta_s^*) &= \Phi \left(\left[\frac{(\sigma^2 + \sigma_\varepsilon^2)}{\sigma^2} \left(\Theta_s^* - \Phi^{-1}(1 - \delta_i) \left(\frac{\sigma^2 \sigma_\varepsilon^2}{\sigma^2 + \sigma_\varepsilon^2} \right)^{-1/2} \right) - \mu(s) \frac{\sigma_\varepsilon^2}{\sigma^2} - \Theta_s \right] / \sigma_\varepsilon \right) \\ &= \Phi \left(\frac{\Theta_s^* - \Theta_s}{\sigma_\varepsilon^2} + \frac{\sigma_\varepsilon^2}{\sigma^2} (\Theta_s^* - \mu(s)) - \frac{\sigma^2}{(\sigma^2 + \sigma_\varepsilon^2)^{1/2}} \Phi^{-1}(1 - \delta_i) \right) \end{aligned}$$

signals that is equal to or lower than γ_i^* is expressed as

$$F(\delta_i | s, \Theta, \Theta_s^*) = \int_{\gamma^*(\delta_i, \Theta_s^*)} f(\gamma) d\gamma$$

Using Bayesian updating, the realization of δ_i given private signal γ_i is normally distributed such that for a given γ_i , the belief associated will follow

$$\begin{aligned} \delta_i &= 1 - G(\Theta_s^* | \gamma_i, s) \\ &= 1 - \Phi \left(\left(\frac{\sigma^2 \sigma_\varepsilon^2}{\sigma^2 + \sigma_\varepsilon^2} \right)^{1/2} \left(\Theta_s - \frac{\gamma_i \sigma^2 + \mu(s) \sigma_\varepsilon^2}{\sigma^2 + \sigma_\varepsilon^2} \right) \right) \end{aligned}$$

Noting that there is a one-to-one mapping between private signal γ_i and the belief δ_i , the

Taking the derivative with respect to the parameters and noting that $\Phi'(\cdot)$ is a density function, the CDF is increasing in δ and Θ_s^* but decreasing in Θ_s . The distribution of beliefs across investors is therefore an equilibrium object. The inference from the private signals on the probability of not having a crisis (δ_i) does not depend on risk aversion or asset holdings.

APPENDIX C

The threshold equilibrium is denoted by Θ_s^* . If realization Θ falls below the threshold, there exists a financial crisis, and vice versa. The threshold satisfies at each state s

$$\begin{aligned} \Omega(s, \Theta_s^*) &\equiv \sum_i \omega(s, \delta_i) \\ &= \sum_i \alpha_i(s) \int \lambda(s, \delta_i) dF(\delta | s, \Theta, \Theta_s^*) \end{aligned} \tag{C1}$$

The withdrawal has the following properties:

$$\frac{\partial \Omega(s, \Theta_s^*)}{\partial \mu} < 0; \quad \frac{\partial \Omega(s, \Theta_s^*)}{\partial \gamma} > 0; \quad \frac{\partial \Omega(s, \Theta_s^*)}{\partial \Theta} < 1$$

Proof:

This largely relies on the proof from the previous two results, after expressing the aggregate liquidation $\Omega(s, \Theta_s^*)$ as (C1). Taking the derivative with respect to $\mu(s)$ and γ and using the chain rule will contain the terms of the derivatives of $\lambda(s, \delta_i)$ and CDF $F(\cdot)$ with respect to the parameters. Note that the results from the previous propositions, both $\lambda(s, \delta_i)$ and CDF $F(\cdot)$, are decreasing in $\mu(s)$ but increasing in γ_i . The derivative with respect to

subj

$$\sum_i \alpha_i(s, \delta_{ii}) = \sum_i e_i(s) L_i = e(s)$$

$$\sum_s q(s) \alpha_i(s) = e_i(s) L_i$$

From Appendix A, the liquidation decision $\omega(s, \delta_i)$ is a linear function of the asset holdings $\alpha_i(s)$ given the feature of the CRRA utility function. Therefore, the optimization problem is rewritten as follows:

$$L(s, \delta_i, \gamma_i) = \max_{\alpha_i(s)} \sum_z p(s) M(s, \delta_i; \gamma_i) \cdot \frac{\alpha_i(s)^{1-\gamma_i}}{1-\gamma_i}$$

where

$$M(s, \delta_i; \gamma_i) = E_\delta \left\{ \frac{1}{1-\gamma_i} \left[\delta_i [D - (R-D)\lambda(s, \delta_i)]^{1-\gamma_i} + (1-\delta_i) [R_c + (D-R_c)\lambda(s, \delta_i)]^{1-\gamma_i} \right] \middle| \Theta_s^* \right\}$$

Θ could be decomposed similarly. It is noted that the withdrawal decision $\lambda_i(s, \delta)$ given Θ_s^* is independent of Θ , and the derivative of the CDF $F(\cdot)$ with respect to Θ is positive but smaller than unity. $\square$

APPENDIX D

An additional component of the optimization problem introduces the difference in cross-sectional asset holdings such that if the bad state of an economy were realized, the asset holding for risk-averse investors would become relatively larger in share.

Proof:

The optimization problem is expressed as

subj

$$\sum_i \alpha_i(s, \delta_{ii}) = \sum_i e_i(s) L_i = e(s)$$

$$\sum_s q(s) \alpha_i(s) = e_i(s) L_i$$

where $p(s)$ is the probability of state s . Taking the derivatives and the first-order conditions become

$$p(s) \cdot M(s, \delta_i; \gamma_i) \cdot \alpha_i(s)^{1-\gamma_i} = \eta q(s)$$

$$\sum_i \left[\frac{M(s, \delta_i; \gamma_i)}{M(s, \delta_j; \gamma_j)} \alpha_j(s; \gamma_j)^{\gamma_j/\gamma_i} \right] - e(s) = 0$$

The cross-sectional asset holdings vary across aggregate states. Investors with higher risk

$$L(s, \delta_i, \gamma_i) = \max E \left\{ \frac{1}{1-\gamma_i} \left[\delta_i [D \alpha_i(s) - (R-D)\omega(s, \delta_i)]^{1-\gamma_i} + (1-\delta_i) [R_c \cdot \alpha_i(s) + (D-R_c)\omega(s, \delta_i)]^{1-\gamma_i} \right] \middle| \Theta_s^* \right\}$$

aversion will carry asset holdings predominantly into good states. In states with low aggregate endowment, the asset holdings are predominantly held by the risk-averse participants, that is, SWFs.

Proof:

The effect of aggregate state (s) on the relative holding in risky assets ($\alpha_i(s)/e_i(s)L_i$) can be obtained by taking the first-order derivative and applying the implicit function theorem as follows:

$$\begin{aligned} \frac{\partial[\alpha_i(s)/e_i(s)L_i]}{\partial s} &= \frac{\partial[\alpha_i(s)/e_i(s)L_i]}{\partial e_i(s)} \cdot \frac{\partial e_i(s)}{\partial s} \\ &+ \frac{\partial[\alpha_i(s)/e_i(s)L_i]}{\partial \mu(s)} \cdot \frac{\partial \mu(s)}{\partial s} \\ &+ \frac{\partial[\alpha_i(s)/e_i(s)L_i]}{\partial \Theta_s^*} \cdot \frac{\partial \Theta_s^*}{\partial s} \end{aligned}$$

The first term shows how endowments affect the risk-sharing rule as in the general case, taking the leverage into consideration. The effect on asset allocation arising from the liquidation stage comes from the second and third terms. Using the implicit theorem,

$$\begin{aligned} \frac{\partial[\alpha_i(s)/e_i(s)L_i]}{\partial s} &= \frac{\alpha_i(s)}{e_i(s)L_i} \left[\frac{1}{\partial e_i(s)} \left(\frac{\bar{\gamma} - \gamma}{\gamma} \right) \frac{\partial e_i(s)}{\partial s} \right. \\ &\left. + \frac{\bar{\gamma}}{\gamma} V(s; \gamma_i) \cdot \left(-\frac{\partial \mu(s)}{\partial s} + \frac{\partial \Theta_s^*}{\partial s} \right) \right] \end{aligned}$$

where

$$\bar{\gamma} \equiv \left[\sum_i \frac{\alpha_i(s; \gamma_i)}{e_i(s)L_i} \cdot \frac{1}{\gamma_i} \right]^{-1}$$

$$\begin{aligned} V(s; \gamma_i) &\equiv \sum_i \frac{\alpha_i(s; \gamma_i)}{e_i(s)L_i} \cdot \frac{1}{\gamma_i} \\ &\cdot \frac{\partial[\ln M(s, \delta_i; \gamma_j) - \ln V(s; \gamma_i)]}{\partial \Theta_s^*} \end{aligned}$$

The first term in the bracket is negative for investors with a risk aversion higher than the average. Similarly, $V(s; \gamma_i)$ is also negative for investors with higher degrees of risk aversion. Therefore, the general effect of aggregate state is reinforced by the additional component.

APPENDIX E

The transmission mechanism of how bad fundamentals could turn into a financial crisis consists of three effects. Taking the derivatives with respect to the state s on the probability of crisis:

Proof:

$$\begin{aligned} \frac{\partial \phi(s)}{\partial s} &= \frac{\partial \Phi'(s)}{\partial \mu(s)} \cdot \frac{\partial \mu(s)}{\partial s} + \frac{\partial \Phi'(s)}{\partial \Theta_s^*} \cdot \frac{\partial \Theta_s^*}{\partial s} \\ &= -\frac{1}{\sigma} \phi(\cdot) \frac{\partial \mu(s)}{\partial s} + \frac{1}{\sigma} \phi(\cdot) \frac{\partial \Theta_s^*}{\partial s} \end{aligned}$$

Following the results in Appendix C and D, the last term could be expressed as

$$\begin{aligned} \frac{d\Theta_s^*}{ds} &= \left[\sum_i \frac{d\alpha_i(s; \gamma_i)/e_i(s)L_i}{e_i(s)} \cdot \frac{de_i(s)}{ds} \Omega(\mu(s), \Theta_s^*) \right] / \\ &\left[1 + \sum_i \frac{d\alpha_i(s; \gamma_i)/e_i(s)L_i}{\mu(s)} \Omega(\mu(s), \gamma_i, \Theta_s^*) \right] \\ &+ \left[\sum_i \frac{d\alpha_i(s; \gamma_i)/e_i(s)L_i}{\mu(s)} \Omega(\mu(s), \gamma_i, \Theta_s^*) \right. \\ &\left. + \sum_i \frac{\alpha_i(s; \gamma_i)}{e_i(s)} \cdot \frac{d\Omega(\mu(s), \gamma_i, \Theta_s^*)}{d\mu(s)} \right] \frac{d\mu(s)}{ds} \end{aligned}$$

Collecting terms to arrive at the three channels in the transmission mechanism,

$$\begin{aligned} \frac{\partial \phi(s)}{\partial s} &= \left[\frac{\partial \Phi'(s)}{\partial \mu(s)} \cdot \frac{\partial \mu(s)}{\partial s} + \frac{\partial \Phi'(s)}{\partial \Theta_s^*} \cdot \frac{\partial \Theta_s^*}{\partial \mu(s)} \cdot \frac{\partial \mu(s)}{\partial s} \right] \\ &+ \frac{\partial \Phi'(s)}{\partial \Theta_s^*} \cdot \frac{\partial \Theta_s^*}{\partial e(s)} \cdot \frac{\partial e(s)}{\partial s} < 0 \end{aligned}$$

From above equation,

$$\begin{aligned} \frac{\partial \phi(s)}{\partial s} &= -\frac{1}{\sigma} \phi(.) \frac{\partial \mu(s)}{\partial s} + \frac{1}{\sigma} \phi(.) \left\{ \left[\sum_i \frac{d\alpha_i(s; \gamma_i)/e_i(s)L_i}{e_i(s)} \cdot \frac{de_i(s)}{ds} \Omega(\mu(s), \gamma, \Theta_s^*) \right] / \left[1 + \sum_i \frac{d\alpha_i(s; \gamma_i)/e_i(s)L_i}{\mu(s)} \Omega(\mu(s), \gamma, \Theta_s^*) \right] + \right. \\ &= \underbrace{-\frac{1}{\sigma} \phi(.) \frac{\partial \mu(s)}{\partial s}}_{\text{fundamental channel}} + \underbrace{\frac{1}{\sigma} \phi(.) \left[\sum_i \frac{d\alpha_i(s; \gamma_i)/e_i(s)L_i}{\mu(s)} \Omega(\mu(s), \gamma_i, \Theta_s^*) + \sum_i \frac{\alpha_i(s; \gamma_{ii})}{e_i(s)} \cdot \frac{d\Omega(\mu(s), \gamma_i, \Theta_s^*)}{d\mu(s)} \right] \frac{\partial \mu(s)}{\partial s}}_{\text{information channel}} \\ &\quad + \underbrace{\frac{1}{\sigma} \phi(.) \left[\sum_i \frac{d\alpha_i(s; \gamma_i)/e_i(s)L_i}{e_i(s)} \Omega(\mu(s), \gamma_i, \Theta_s^*) \right] / \left[1 + \sum_i \frac{d\alpha_i(s; \gamma_i)/e_i(s)L_i}{\mu(s)} \Omega(\mu(s), \gamma_i, \Theta_s^*) \right] \frac{de_i(s)}{ds}}_{\text{risk-sharing channel}} \end{aligned}$$

The transmission mechanism is therefore decomposed into three channels: the fundamental channel (first term), the information channel arising from the interactions between investors (second term) and the risk-sharing channel (third term). Following the previous Appendices A–D, the first term is negative. For investors with a risk-aversion parameter higher than the

weighted average across individuals, it increases their weight in cross-sectional asset holding when bad fundamentals occur. Their withdrawal is higher and it increases the likelihood of the financial crisis. The aggregate effect across individual investors is negative given the weighted averages and the predominant effect arising from high risk-aversion investors.

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