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Risk sharing versus financial contagion in Asia: An asset price perspective

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Abstract

This paper assesses financial integration in Asia in terms of risk-sharing benefit versus financial contagion cost. We construct a new measure of risk sharing based on a term structure model, which allows identification of realized stochastic discount factors. Risk sharing is low in Asia, and varies across time and countries, whereas contagion risks are more significant intra-regionally, and relatively stable over the past decade. An overall tradeoff exists between risk sharing and contagion, but the terms of tradeoffs vary across countries, depending on relative economic fluctuations and inflation differentials. Asia therefore can potentially enhance risk sharing without raising contagion risk.
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1. Introduction

Financial integration holds a great promise in theory. It is expected to be a catalyst for (i) transferring resources from less productive to more productive regions, (ii) allowing countries to diversify and insure against idiosyncratic shocks via risk sharing, and (iii) fostering financial market development, and hence growth and macroeconomic stability, among others. Evidence of how much these benefits have materialized in practice is at best mixed in the last two cases (Kose et al., 2009; Nicolo and Juvenal, 2010), but near absent in the first (Lucas, 1990). Meanwhile, the opposing view that financial integration brings with it costly financial crises, amplified by contagion and spillover effects, has recently gained ground, propelled not least by the global financial crisis. There is a growing discomfort that financial integration is not only a double-edged sword, but may be integral to how financial crises arise and are exacerbated internationally (Stiglitz, 2004, 2010b; Devereux and Yetman, 2010b).

The lack of clarity about the extent of benefits from financial integration and the potential cost involved pose a dilemma to policy makers, especially in emerging market countries. Asian economies have stepped up efforts to foster more intra-regional financial integration after the 1997 financial crisis, in a bid to reduce reliance on bank and foreign funding with a conviction that the integration will fortify the regional financial system and bring net economic benefits to the region. Should the policy makers continue to promote more regional financial integration to accelerate the benefit, or should these efforts now be put in reverse to curb the risks of financial contagion and preempt systemic disruption emanating from closer and more complex financial linkages?

This paper contributes to the debate by assessing financial integration in Asia jointly from both benefit and cost perspectives. We focus on the risk management function of financial integration where the tension is most distinct: the benefit is enjoyed if financial integration allows risks to be shared across borders, while the cost is incurred when risks spill over from one country to another. We quantify the extent of risk sharing and contagion risks using a novel asset price approach which offers a number of advantages. Our estimates show that intra-regional risk sharing in Asia is low both in absolute term (i.e. far lower than the full risk-sharing benchmark), and relative to the degree of risk sharing vis-à-vis the US or EU. By contrast, intra-regional contagion spillovers are found to be more evident. A joint examination of risk sharing and contagion risks reveals a discernible tradeoff to financial integration, but the terms of tradeoff are found to vary widely across countries. These differences, we show, depend on certain contextual factors, which

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help explain why financial integration is more successful for some countries than others.

Our results suggest that Asia is yet to make the most out of the existing degree of financial integration, and there is a room for more risk-sharing benefit to be obtained without necessarily raising the cost of contagion risks. One clear option for policy makers is to continue promoting financial market developments, to enhance the risk-sharing function of the financial markets. Our findings point towards other possibilities that should not be overlooked. For instance, better and more coordinated cyclical macroeconomic management can help both directly by keeping risks low, and indirectly by enhancing the risk-sharing capability. In general, since benefits of financial integration can vary over the cycles, the role of policy should extend beyond an establishment of appropriate infrastructure or other structural settings.

Methodologically, our approach contains several novel features that set this paper apart from the literature. The measure of risk sharing is grounded on the asset-pricing theory prediction that stochastic discount factors should be equalized under perfect risk sharing. Unlike previous studies, we attempt to estimate *ex post* realization of stochastic discount factors directly, drawing on information contained in government bond yield curves together with an identifying restriction imposed by a no-arbitrage affine term structure model. Financial contagion, on the other hand, is estimated as the extent of tail event spillovers from one stock market to another, through the estimation of quantile regressions of stock returns (based on the 'CoVaR' approach due to Adrian and Brunnermeier, 2010). Our attempt to characterize the terms of cost–benefit tradeoffs to financial integration is, to our knowledge, the first empirical exercise of its kind.

The paper is organized as follows. Section 2 introduces our asset-pricing analytical framework and describes the broad empirical objectives. Section 3 lays out the details of how a term structure model and bond yields can be used to construct a measure of risk sharing. The estimates of contagion risks and the implied cost–benefit tradeoffs to financial integration is the topic of Section 4. An exploration of how the heterogeneity of the tradeoffs can be explained by contextual factors is pursued in Section 5, before Section 6 concludes.

2. The asset price framework

Asset prices are a rich source of information and have often been relied on to provide unique insights to the study of financial integration. For example, in measuring the extent of financial integration, the 'price-based' approach, which makes use of the law of one price, such as covered interest parity conditions, is as popular as the 'quantity-based' approach, which draws on sizes of cross-border flows and asset holdings. See Cavoli et al. (2004) for a survey.

This paper bypasses the issue of the extent of financial integration, and instead focuses directly on the implications of greater financial integration in terms of risk sharing and financial contagion. Given these objectives, we argue that the asset price approach can be even more insightful. This is self-evident in the case of financial contagion which is fundamentally an asset-price concept, e.g. even a large coordinated portfolio investment outflow can hardly be termed a financial contagion in the absence of an extreme and correlated fall in asset prices. On the other hand, the degree of international risk sharing is traditionally measured by the cross-country correlation of consumption growth, a quantity-based approach (the seminal paper being Lewis, 1996). Our asset-price approach is rooted on the same theoretical foundation as Lewis (1996), but by looking at asset prices directly, we do not have to make any specific assumption about the utility function, which is needed in Lewis (1996) to justify consumption growth as the proxy for the marginal rate of substitution. In addition, our approach relies on higher frequency financial market data and is grounded on a structural asset pricing model, hence can yield more insights on both the degree and nature of risk sharing (for instance, that risk sharing can vary significantly over time, driven by interactions between the amount of risks and prices of risks).

To evaluate the implications of financial integration via the asset-price approach, one clearly needs to go beyond the law of one price. Simple correlation between asset returns is not an appropriate measure of either risk sharing or financial contagion. In this paper, we propose a more refined empirical method, as the next two sections explain.

2.1. Risk sharing

There is perfect risk sharing between countries i and j if and only if the stochastic discount factors for the two countries are equalized[1]:

$$M^i_{t+1} = M^j_{t+1} \tag{2.1}$$

To the extent that there is less than perfect risk sharing, the distance between the two stochastic discount factors indicates the degree of constrained risk sharing. It is natural then that a statistical measure of risk sharing should be based on this distance. Brandt et al. (2006) defines a metric:

$$BCS_{i,j} = 1 - \frac{\text{var}(\log\ M^i_{t+1} - \log\ M^j_{t+1})}{\text{var}(\log\ M^i_{t+1}) + \text{var}(\log\ M^j_{t+1})} \tag{2.2}$$

which ranges from −1 to 1, with a higher number indicating better risk sharing. We shall refer to this metric as the Brandt–Cochrane–Santa-Clara (*BCS*) index.

The stochastic discount factors M^i_{t+1} and M^j_{t+1} are of course unobserved, prompting many researchers to resort to an indirect inference approach. For example, Brandt et al. (2006) assumes a cross-border no-arbitrage condition which implies that

$$\log\ M^i_{t+1} = \log\ M^j_{t+1} + \log \frac{e_{t+1}}{e_t} \tag{2.3}$$

[1] The stochastic discount factors intuitively measure the marginal rates of substitution in the two countries, which, if equalized, imply perfect risk sharing because all country-specific shocks are shared equally. See Cochrane (2001).

where e_t is the spot price of j's currency per one unit of i's currency.[2] They then substitute the numerator of the *BCS* index by var(log(e_{t+1}/e_t)). Since the stochastic discount factors are known to be much more volatile than the exchange rates, the *BCS* index should be close to 1 and they conclude that the degree of risk sharing must be high (or the exchange rates are too smooth).

An alternative and more direct way to test the hypothesis of perfect risk sharing is to estimate the stochastic discount factor directly. Various attempts in the literature have focused on some moments of the discount factors, however. For instance, Flood and Rose (2005) and Hanhardt and Ansotegui (2009) start by expanding the fundamental asset pricing equation:

$$\begin{aligned} P_t^i &= E_t(M_{t+1}^i X_{t+1}^i) \\ &= E_t(M_{t+1}^i)E_t(X_{t+1}^i) + Cov_t(M_{t+1}^i X_{t+1}^i) \end{aligned} \tag{2.4}$$

where P_t^i is the asset's price and X_{t+1}^i the payoff of the asset. Their strategy then consists of writing down a factor model for $Cov_t(M_{t+1}^i X_{t+1}^i)$ and using stock prices to back out $E_t(M_{t+1}^i)$.

In this paper, we will use the fundamental asset pricing equation as the core of our building block to examine the stochastic discount factors directly. Our point of departure is to estimate the actual realization of M_{t+t}^i for each market i, not just its first moment. The distinction, our results will show, is important because a large part of fluctuations in M_{t+t}^i is driven by the interactions between prices of risks and realized shocks. Looking at the prices of risks alone, via the expectation of $E_t(M_{t+1}^i)$, does not give a complete picture of how successful risk sharing mechanism works in periods of high volatility. As a matter of pure principles, it is also unclear why $E_t(M_{t+1}^i)$ should provide a good basis for evaluating risk sharing.[3]

There is no known method for extracting the realized stochastic discount factors from the stock market data, as there is simply not enough information contained in a univariate variable such as a stock index. We propose a new approach, drawing on government bond term structure which is a much richer source of information. We retain the assumption that there is no-arbitrage within any given country i, so that there exists a positive random variable M_{t+1}^i pricing all domestic assets, and attempt to estimate it directly using suitable identifying restrictions. These restrictions derive from the no-arbitrage conditions set in the context of an affine term structure model. The market is assumed to be complete within each country, so that the estimated stochastic discount factor is indeed the unique one.[4] We do not assume cross-border no-arbitrage, therefore Eq. (2.3) needs not hold. Instead, the estimated time-series of M_{t+1}^i can be used to construct the *BCS* index directly.

2.2. Contagion

Critics of financial globalization often point out the systemic nature of risks in an intricate global financial network, where disruptions in one region can spread throughout the system in a financial contagion. Such a suboptimal outcome can arise in the presence of market imperfections, such as incomplete credit markets in Allen and Gale (2001), or non-convex production technology in Stiglitz (2010a). More generally, there is a growing recognition of the importance of financial accelerator mechanism, enabled by interconnected financial market and intermediaries and financial frictions, in exacerbating the impact of shocks on the real economy (see Gertler and Kiyotaki, 2010 and references therein). A growing appreciation of these downside risks has led some to question the wisdom of promoting more financial integration, e.g. through further liberalization of capital accounts (see Stiglitz, 2010b).

In this paper, we acknowledge the possibility of financial contagion without subscribing to any particular theory of why or how it arises, and focus on how to empirically account for it as the cost to financial integration. There are some basic criteria for a good measure of contagion cost in our application. First, the cost should not be accounted for only when an actual contagion or crisis occurs, but instead should reflect the degree of risk exposure, i.e. the shadow price paid by integrating more closely with other markets. Secondly, a measure of contagion should go beyond the notion of simple correlation, and focus on the cross-market spillover at the negative tail of the distribution, i.e. when a stress in one market brings about a stress in another market. Finally, in order to evaluate the contagion cost along side the benefit of risk sharing, it must be possible to express in aggregate how exposed one market is to contagion, compared to another.

In light of these considerations, this paper applies a simple statistical measure of 'CoVaR' (Conditional Value-at-Risk) due to Adrian and Brunnermeier (2010) to equity markets.[5] Intuitively, the CoVaR concept measures the extent to which a tail event in one market can spill over and create or worsen a tail event in another market. This measure is computed by performing quantile regressions of one asset returns conditional on another, thus the attention is squarely on tail correlation. The estimated coefficient or 'beta' then describes the degree of exposure to the financial contagion risk. Aggregating the magnitude of spillovers stemming from different countries gives a measure of one country's exposure as desired. We draw on returns of stocks rather than bonds when computing CoVaR, because

[2] Eq. (2.3) is based on the premise that asset j, when denominated in i's currency, must also be priced by M_{t+1}^i and vice versa. Thus the condition can be interpreted as a parity condition. See detailed derivation in Backus et al. (2001).

[3] Assuming a homethetic utility function form in an optimal consumption problem, M_{t+1} is reduced to consumption growth. Cochrane (2001, p. 57) says of risk sharing condition: "This prediction is so radical, it is easy to misread it at first glance. It does not say that *expected* consumption growth is equal: it says that *ex post* consumption growth is equal."

[4] With incomplete markets, there is no unique stochastic discount factor, and the estimate of M_{t+1}^i represents the pricing kernel projected on the space of bond returns. In this case, the discount factor and the measure of risk sharing are specific to the bond market. It is notable, however, that the estimate of M_{t+1} obtained below for the case of US has moments that are similar to prior estimates based on the stock market.

[5] A number of alternative measures are available: Diebold and Yilmaz (2009) construct a measure of spillover based on variance decomposition of VARs in return and volatilities, while Engle et al. (2009) proposed a class of Multiplicative Error Model (MEM), a GARCH-based measure of volatility spillovers. As Section 4.1 will show, our results are broadly consistent with these studies.

of the close association between the stock market and financial crises as well as times of stress in general.

3. Measuring risk sharing from bond prices

Our key identification strategy is to exploit the information contained in the term structure of government bond markets, and extract the underlying stochastic discount factors M_{t+1} directly using an affine term structure model. Bonds are a unique asset class for this purpose, given their term structure characteristic (unlike, e.g. stocks). This means that the information about expectation of the future is inherent in a yield curve, allowing explicit modeling of deviations from expectations and associated prices of risks, both of which are central components of M_{t+1}. The important identifying assumption is that there is no arbitrage opportunity within any bond market, so that there exists a single M_{t+1} that prices all bonds in any given market.

3.1. Affine term structure model

This section briefly reviews the key ingredients of the affine term structure model.[6] Assume that there is a state vector X_t which evolves as a VAR process of order 1:

$$X_t = \mu + KX_{t-1} + \Sigma\varepsilon_t \tag{3.1}$$

where $\varepsilon_t \sim N(0, I)$. The choice of X_t throughout this paper will be the first three principal components of the term structure, which are known to be flexible enough in describing any shape of yield curve. The risk-free one-period interest rate is assumed to be an affine function of the state variable:

$$r_t = \delta_0 + \delta_1' X_t \tag{3.2}$$

Under no-arbitrage assumption, the fundamental asset pricing applied to bonds is given by

$$P_{n,t} = E_t(M_{t+1} P_{n-1,t+1}) \tag{3.3}$$

where $P_{n,t}$ is the price of n-period zero-coupon bond at time t, and M_{t+1} is the stochastic discount factor. We adopt a typical assumption that M_{t+1} is lognormal, taking the form

$$M_{t+1} = exp\left[-r_t - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t'\varepsilon_{t+1}\right] \tag{3.4}$$

where the λ_t, the price of risk, is also affine in the state variable:

$$\lambda_t = \Lambda_0 + \Lambda_1 X_t \tag{3.5}$$

The system of Eqs. (3.1)–(3.5) describes the elements of an affine term structure model. Solving the pricing kernel equation (3.3) recursively backwards, using as a terminal condition $P_{0,t+1} = 1$, and substitute for r_t and λ_t, the solution for the log bond price, $p_{n,t} \equiv \log P_{n,t}$, can be shown to be affine in the state as well

$$p_{n,t} = A_n + B_n' X_t \tag{3.6}$$

where A_n and B_n are solutions to the following system of difference equations

$$\begin{aligned} A_n &= A_{n-1} - \delta_0 + B_{n-1}'(\mu - \Sigma\Lambda_0) + \frac{1}{2}B_{n-1}'\Sigma\Sigma' B_{n-1} \\ B_n' &= B_{n-1}'(K - \Sigma\Lambda_1) - \delta_1' \end{aligned} \tag{3.7}$$

with initial conditions $A_1 = -\delta_0$ and $B_1' = -\delta_1'$. Given these solutions, the log gross yield $y_{n,t} \equiv \log(1 + Y_{n,t}) = -p_{n,t}/n$ is clearly also affine in the state

$$y_{n,t} = -\frac{A_n}{n} - \frac{B_n'}{n} X_t \tag{3.8}$$

3.2. Estimation

The data set consists of monthly time-series of zero-coupon government bond yields obtained from Bloomberg (see Appendix A for details) which covers 13 countries including Japan, Hong Kong, Korea, Singapore, Taiwan, Indonesia, Malaysia, the Philippines, Thailand, China, India, US and EU (approximated by the German Bund). The series start from January 2000 to May 2011 for all countries except Indonesia (starting from February 2003) and China (starting from September 2003). The available maturities are 3-month, 1-year, 2-year, 5-year, 10-year and 15-year.

The empirical objective is to obtain an estimate of M_{t+1} which is most consistent with the time-series of observed zero-coupon yields while respecting the restrictions imposed by no-arbitrage affine model. Since the functional form of M_{t+1} is assumed, the problem is simply that of parametric estimation. One approach is to assume that yields are observed with gaussian errors and estimate the parameters $\theta = \{\mu, K, \Sigma, \delta_0, \delta_1, \Lambda_0, \Lambda_1\}$ using the maximum likelihood method which effectively minimizes the sum of squared error between observed yields and the fitted values, $\sum_{n=1}^{N}\sum_{t=1}^{T}(y_{n,t} - \hat{y}_{n,t})^2$.

However, the maximum likelihood method is notoriously expensive to implement, given that the likelihood surface is highly nonlinear in the parameters with no closed-form solution. Unless one starts the numerical optimization with a good set of initial conditions for the parameters, the estimates may only give local optima. Searching for the global optimal can therefore be very costly, particularly in our case since the same procedure must be repeated for each of the 13 countries.

To circumvent this problem, we first execute an alternative estimation procedure, recently proposed by Adrian and Moench (2010), which is asymptotically consistent and implementable by multi-step cross-sectional linear regressions along the line of Fama and Macbeth (1973). Their basic insight is to express the model in the space of excess returns instead of yields, which makes the model tenable to linear estimation. See Appendix B for a brief overview of the steps and rationale for this procedure.

Our estimation strategy is to first use the Adrian–Moench method to obtain a set of first-round estimates, before refining the estimates with maximum likelihood at a significantly reduced cost given a good set of initial conditions. Specifically, for each country we perform the following set of computations:

[6] See Dai and Singleton (2000), Duffee (2002) and Ang and Piazzesi (2003) among others for details on how an affine model is specified and solved.

Table 1
Affine term structure model fit.

RMSE (%)	Adrian–Moench	After refinements	Unrestricted
Japan	0.0786	0.0252	0.0127
Hong Kong	0.0707	0.0430	0.0346
Korea	0.1842	0.0519	0.0396
Singapore	0.0722	0.0441	0.0323
Taiwan	0.0346	0.0282	0.0256
Indonesia	0.4130	0.1936	0.1283
Malaysia	0.1145	0.0571	0.0480
The Philippines	0.4327	0.1612	0.1495
Thailand	0.0696	0.0488	0.0429
China	0.0776	0.0595	0.0497
India	0.1005	0.0665	0.0517
US	0.0631	0.0498	0.0400
EU	0.0388	0.0270	0.0180

Table 2
Summary statistics of m_{t+1}.

	Mean	S.D.
Japan	−0.26	1.01
Hong Kong	−0.11	0.51
Korea	−0.33	0.89
Singapore	−0.18	0.63
Taiwan	−0.19	0.67
Indonesia	−0.30	1.64
Malaysia	−0.23	0.64
The Philippines	−0.26	0.97
Thailand	−0.13	0.52
China	−0.21	0.83
India	−0.13	0.68
US	−0.17	0.55
EU	−0.09	0.34

1 Interpolate the yield curve in each time period, using piecewise cubic Hermite polynomial.[7] Use the interpolated yields to compute the first three principal components, log prices, and excess returns over 1-month holding period. The 1-month yield serves as the short-term interest rate r_t.
2 Estimate a VAR in the three principal components, to get estimates for μ, K, Σ and the associated residual ε_t. Regress the short-term interest rate r_t on the state variables to obtain δ_0 and δ_1. These estimates are treated as fixed.
3 Implement the Adrian–Moench procedure to obtain $\hat{\Lambda}_0$ and $\hat{\Lambda}_1$ (see Appendix B).
4 Refine the estimates via a maximum likelihood routine, by choosing Λ_0 and Λ_1 to minimize the sum of squared yield fit errors, $\sum_{n=1}^{10}\sum_{t=1}^{T}(y_{n,t}-\hat{y}_{n,t})^2$, setting the initial conditions for Λ_0 and Λ_1 equal to $\hat{\Lambda}_0$ and $\hat{\Lambda}_1$ obtained from the previous step.
5 Recover the log stochastic discount factor $\log M_{t+1} \equiv m_{t+1} = -r_t - \lambda_t'\lambda_t - \lambda_t'\varepsilon_{t+1}$.

This procedure is indeed fast to implement. Step 4 in particular is now much faster than a typical maximum likelihood routine with random initial conditions. Furthermore, the refined optimal values are in all cases within a close proximity of $\hat{\Lambda}_0$ and $\hat{\Lambda}_1$, suggesting that the Adrian–Moench procedure is effective in pinning down the likely range of the true parameters. Refinements on the other hand helps improve the goodness of fit noticeably in most cases, as shown by the root mean squared errors presented in Table 1. The errors of refined estimates are moreover only a few basis points higher than the lower bound implied by the unrestricted linear model, shown in the last column, which regresses yields directly on the three principal components. Thus our multiple-round estimation procedure is effective in both (i) keeping the estimation cost low, and (ii) obtaining a good fit for the model and, by implications, a reliable estimate of m_{t+1}.

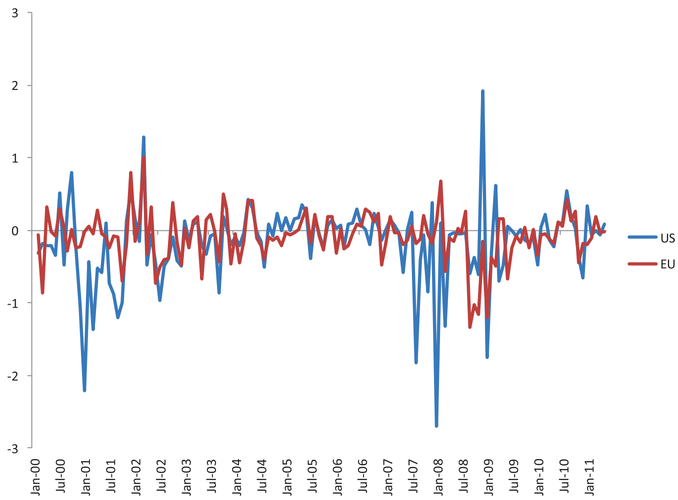
Table 2 presents summary statistics for our estimates of log stochastic discount factors. The discount factors are volatile, but at a scale that is similar to prior findings on stock market data. The volatility in the US case of 0.55 is almost the same as 0.50 which is a typical stock market benchmark obtained from Hansen-Jagannathan bound using 8% mean excess return and 16% standard deviation (Hansen and Jagannathan, 1991). For all countries, almost all of the movements in discount factors are explained by time-varying risks and their prices rather than movements in the short-term interest rates. The volatilities of discount factors also dominate those of exchange rates, which are no higher than 0.13 per year in our sample, consistent with the observation of Brandt et al. (2006). Therefore our method of extracting the discount factors from the bond market yields results that are broadly consistent with prior estimates in terms of moments.

3.3. Risk sharing measures

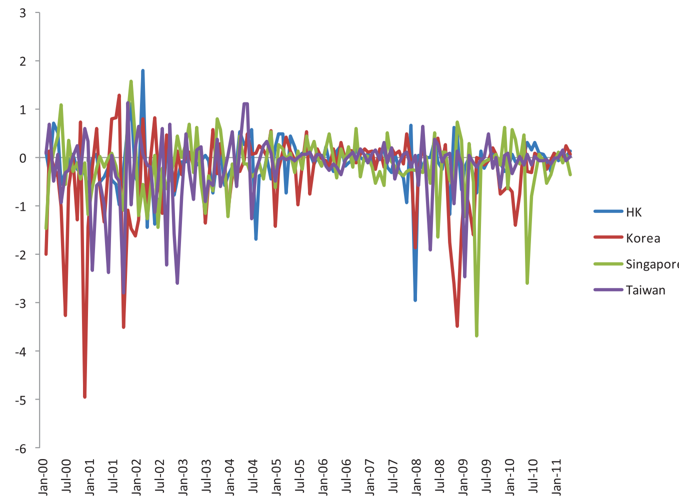
When it comes to measuring the degree of risk sharing between country pairs however, the moments alone are less informative, precisely because the discount factors fluctuate so much over time. It is necessary to track how similar any pair of discount factors are over time. Fig. 1 plots the time-series of m_{t+1} for selected countries. Fig. 1(a) plots the discount factor for the US together with that of EU. The two series are similar in levels and tend to co-move closely over time, particularly so during the so-called great moderation period of 2002–2007, and again after the global financial crisis. Such close relationship between the discount factors is much less visible for the Asian countries, whether among the newly industrialized economies (NIEs) consisting of Hong Kong, Korea, Singapore and Taiwan (Fig. 1(b)), or ASEAN3 including Malaysia, the Philippines and Thailand (Fig. 1(c)). The discount factors for these countries are both more volatile and less correlated with each other, lending little evidence of intra-regional risk sharing whether among NIEs or ASEAN.

To evaluate the degree of risk sharing more objectively, we compute the *BCS* index (Eq. (2.2)) for all pairs of 13 countries. The results are shown in Table 3(a). Broadly speaking, the degree of risk sharing between the 13 countries is moderate at best: the *BCS* indices average at 0.10, significantly below the full risk-sharing benchmark of 1. At the same time, behind this average

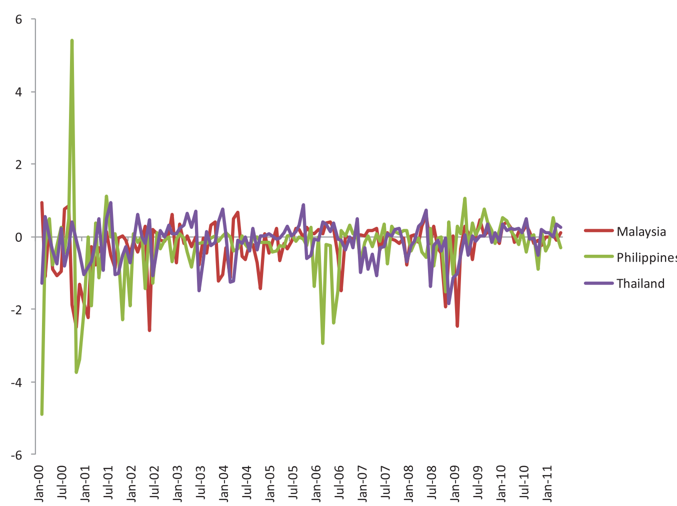
[7] We choose this method over cubic spline to avoid excessive oscillation that otherwise would arise intermittently in the sample.



(a) US and EU



(b) NIEs



(c) ASEAN3

Fig. 1. (a–c) Log stochastic discount factors.

number lies much heterogeneity, with certain pairs of countries sharing risks more successfully than others. Those with above average risk sharing are marked with light color, while those with *BCS* higher than one standard deviation from the mean (0.22) are in dark color.

Notable cases include the risk sharing between the US and Hong Kong, whose *BCS* index is the highest at 0.587. A very close financial integration together with a common monetary policy between the two economies mean that risks in the UK and Hong Kong are similarly priced, an evidence of significant risk sharing. Meanwhile the US and EU share a significant amount of risks relative to others, reaffirming our earlier observation. The result may again not be surprising given the high degree of financial development and integration between the two economies. In contrast, however, Japan does not share risks meaningfully with the US or EU despite having a well-developed financial market, suggesting that risk sharing is a function of much more than financial integration.

Intra-regional risk sharing in Asia remains low, for both NIEs and ASEAN4 groups. In Table 3(a), the corresponding *BCS* indices are boxed and labelled A and B, respectively. Among NIEs, only Hong Kong and Singapore are sharing risks above one standard deviation from average. Meanwhile, the extent of risk sharing between NIEs and ASEAN4 is more noticeable, with Korea and Malaysia acting as core members of their groups in sharing risks with the other faction (Table 3(a), box C). The US shares risks significantly with most NIEs, and to a lesser extent with ASEAN4 (Table 3(a), boxes D and E). These results can be summarized in Table 3(b), which aggregate the *BCS* indices across the regions. Our price-based measures are consistent with findings based on quantity-based measures that Asian countries are more financially integrated with major economies outside the region than with those within Asia (see Borensztein and Loungani, 2011; Pongsaparn and Unteroberdoerster, 2011; Cowen et al., 2006 for example).

Table 3
Brandt Cochrane Santa-Clara (*BCS*) indices.

(a) By countries

	Japan	HK	Korea	Singapore	Taiwan	Indonesia	Malaysia	Philippines	Thailand	China	India	US
HK	0.182											
Korea	0.193	0.078										
Singapore	0.076	0.208	0.054									
Taiwan	-0.076	0.059	0.072	0.095								
Indonesia	0.102	-0.023	0.198	0.067	-0.022							
Malaysia	0.186	0.206	0.146	0.116	0.221	0.176						
Philippine	-0.123	-0.043	0.157	0.060	0.007	0.180	-0.022					
Thailand	0.173	0.090	0.269	0.156	0.098	-0.021	0.086	0.166				
China	-0.099	-0.111	0.167	0.131	0.304	0.009	0.222	-0.108	0.007			
India	-0.029	0.055	0.251	-0.004	-0.062	0.012	0.034	0.204	0.254	0.049		
US	0.025	0.587	0.059	0.226	0.127	-0.041	0.137	0.201	0.131	-0.054	0.166	
EU	0.011	0.297	0.086	0.034	0.101	0.025	0.177	0.063	0.049	0.037	0.212	0.338

(b) Summary by regions

	NIE	ASEAN 4	US&EU
NIE	0.095		
ASEAN 4	0.107	0.094	
US&EU	0.190	0.093	0.338

Table 4
BCS over sub periods.

(a) Great Moderation

	NIE	ASEAN 4	US&EU
NIE	0.139	0.070	0.261
ASEAN 4	0.070	-0.053	0.044
US&EU	0.261	0.044	0.730

(b) Global Financial Crisis

	NIE	ASEAN 4	US&EU
NIE	0.044	0.125	0.074
ASEAN 4	0.125	0.151	0.066
US&EU	0.074	0.066	0.153

(c) Recovery

	NIE	ASEAN 4	US&EU
NIE	0.021	0.044	0.197
ASEAN 4	0.044	0.173	0.293
US&EU	0.197	0.293	0.613

As Fig. 1 suggests, the extent of risk sharing may potentially vary over time, possibly driven by both cyclical and structural shifts. To shed light on the nature of these changes over the past decade, the *BCS* indices are computed over three subperiods: (1) the Great Moderation period of January 2002 to June 2007, (2) the Global Financial Crisis from July 2007 to June 2009, and (3) the recovery period from July 2009 to May 2011.[8] Table 4 show the evolution of risk sharing over the past decade.

Risk sharing among the US, EU and NIEs intensified during the Great Moderation, weakened markedly during the crisis, and resumed strongly since the recovery. The benefits of financial integration for these economies have been reaped slowly over the period when shocks and risks were relatively modest. Risks associated with events as severe as the Global Financial Crisis however were little shared between the major economies, and the economies at the center of the crisis, particularly the US, were under-insured by other economies. As a result, the stochastic discount factor of the US became highly volatile and little correlated with other countries' discount factors during the crisis.

Meanwhile, the intra-regional risk sharing within the ASEAN4 steadily climbed over the periods, while for NIEs the opposite is the case. Behind this evolution, both cyclical and structural forces are likely at work. During the Global Financial Crisis, Indonesia, Malaysia and Thailand were jointly sharing a lot of risks, with *BCS* indices in the range of 0.26–0.35. The discount factors in all three economies became more volatile,

8 These subsamples are used for the computation of the *BCS* indices, holding fixed the full-sample estimates of the stochastic discount factors. The subperiod division is inevitably arbitrary. While the Great Moderation for advanced economies may have started as early as the 80s, we exclude the period before 2002 because Asia remained weighed down by legacies from the Asian crisis. Also we adopt mid-2007 as the starting point of the Global Financial Crisis, even though for many the bankruptcy of Lehman Brothers in September 2008 may be the watershed. Our view is that many signs and forms of market stresses have emerged long before Lehman's demise, and the amount of risks to be shared probably have already risen. As Fig. 1 shows, the pattern of risk sharing may have undergone a structure shift as early as the mid-2007.

but remained close to and highly correlated with each other. In other words, as core members of emerging Asian economies, the group underwent an episode of abrupt shift in prices of risks during the crisis, but was able to share risks efficiently. After the recovery took hold, the discount factors stabilized for all ASEAN4, but the *BCS* indices between the Philippines versus Indonesia, Malaysia and Thailand began to increase. The *BCS* indices for Thailand versus Malaysia and Indonesia also stay high, in contrast to the pre-crisis period. These recent developments provides tentative evidence that the recent increase in intra-regional risk sharing may at least partly be structural.

4. Is there tradeoff to financial integration?

Having characterized the progress of financial integration in Asia from the risk-sharing benefit perspective, we now turn to the flip side of the coin. As mentioned in Section 2, one of the risks to financial integration that has received much recent attention is financial contagion. Assessing the extent and characteristics of these contagion risks for Asia is the topic of the next section. With estimates of both the benefits and costs of financial integration, we will then discuss whether there exists a tradeoff between risk sharing and financial contagion in the case of Asia.

4.1. Contagion risks

A measure of contagion risk should differ from the notion of correlation in three aspects: (i) it is one-sided, in that it is concerned with only negative financial shocks, (ii) it is directed rather than pairwise, in that it explicitly measures how shocks spill over from a specific source country to a recipient, and (iii) it measures systemic rather than generalized risks, by focusing squarely on tail events. We use an empirical measure that satisfies all three properties, by estimating how a realization of a negative tail event in one market helps predict the severity of the downside tail event in another market. In other words, we model the tail of the return distribution, conditional on another market's return at the tail. Technically, the estimate follows the 'CoVaR' methodology introduced by Adrian and Brunnermeier (2010), whose application is the construction of systemic risk measure in the banking sector.

The data are weekly returns in the primary equity indices of the same set of countries (see Appendix A for details). The baseline estimation period conforms to that used to estimate risk sharing, covering the week ending January 7, 2000 to June 10, 2011. Weekly rather than monthly data are used primarily to harvest more information at the tails (the same frequency is used in Adrian and Brunnermeier, 2010).

The tail event is defined to be the threshold value on the domain of return distribution, below which the realized return will fall with probability 5%. The tail event for market i is therefore the value-at-risk (VaR) for the weekly return at 5% confidence level, which can be estimated by fitting a quantile regression (Koenker and Bassett, 1978) to the weekly return of market-i stock:

$$ret_t^i = a + b\,ret_{t-1}^i + e_t \tag{4.1}$$

In the restricted model of $b=0$, the fitted value $\hat{a}$ is a sample point estimate of the 5% VaR. However we consider a general model and estimate b, as a simply way to model autoregressive time-varying tail risk:

$$VaR_t^i = \hat{a} + \hat{b}\,ret_{t-1}^i \tag{4.2}$$

To capture contagion, we estimate a similar quantile regression of market i, but this time conditional on concurrent information received from market j:

$$ret_t^i = \alpha + \beta\,ret_{t-1}^i + \gamma\,ret_t^j + \epsilon_t \tag{4.3}$$

The fitted value of regression (4.3), when evaluated at $ret_t^j = VaR_t^j$, defines the notion of conditional VaR, or 'CoVaR' in the terminology of Adrian and Brunnermeier (2010):

$$CoVaR_t^{i,j} = \hat{\alpha} + \hat{\beta}\,ret_{t-1}^i + \hat{\gamma}\,VaR_t^j \tag{4.4}$$

In other words, $CoVaR_t^{i,j}$ measures the size of the potential tail event at market i conditional on the news that a 5% tail event has already occurred in market j. A large and negative $CoVaR_t^{i,j}$ indicates a significant financial contagion from market j to market i. Clearly *CoVaR* as so defined is one-sided, directed (since $CoVaR_t^{i,j} \neq CoVaR_t^{j,i}$ in general) and aims to capture 'tail' risk spillover.

It is useful for interpretation to express *CoVaR* in a relative rather than absolute scale, namely how much additional tail risk is generated for market i as conditions in market j deteriorate from the median return to the 5% value-at-risk. Thus, we define our contagion index from market j to market i as

$$Contag_t^{i,j} = \hat{\gamma}(VaR_t^j - Median^j) \tag{4.5}$$

where $Median^j$ is the median weekly return, computed as the fitted value of regression (4.1) with $b=0$ and confidence level 50%. Large and negative $Contag_t^{i,j}$ means there is a significant degree of downside contagion from market j to i, or equivalently that market i is exposed to systemic risk stemming from stress in market j. We use this *Contag* measure as a gauge of costs accrued to market i, arising from being financially integrated to market j.

Averaging $Contag_t^{i,j}$ across time t gives a mean exposure of market i to market j, denoted $Contag^{i,j}$. The average contagion matrix is presented in Table 5, where the sources of contagion (country j) are listed in rows, while the recipient countries i are on columns. For example, as the stock market return in Singapore deteriorates from its median level to its stressed case of 5% value-at-risk level, our estimate implies that the repercussion on Hong Kong would be equivalent to a 4.147% downward adjustment in the worst case scenario facing Hong Kong. The spillover risks stemming from the financial centre countries, i.e. Hong Kong and Singapore, to others appear to be among the highest according to the estimates. Averaging $Contag^{i,j}$ across i (to get $Contag^j$), highlights Singapore as the most systemic equity market with average $Contag^j$ of −3.181, followed by Hong Kong with $Contag^j$ of −2.986. On the other hand, the most 'exposed' market is Korea, whose $Contag^i = \sum_{\forall j} Contag^{i,j}/12$ is 3.269.

Table 5
Contagion matrix: $Contag^{i,j}$.

j \ i	Japan	HK	Korea	Singapore	Taiwan	Indonesia	Malaysia	Philippines	Thailand	China	India	US	EU	NIEs	ASEAN	US&EU	Average
Japan		-3.046	-4.511	-2.812	-2.863	-3.339	-1.570	-2.375	-2.452	-1.552	-3.289	-2.730	-3.454	-3.308	-2.434	-3.092	-2.833
HK	-3.341		-4.473	-3.862	-3.247	-3.107	-1.842	-1.859	-2.942	-1.702	-3.283	-2.162	-4.011	-3.861	-2.438	-3.087	-2.986
Korea	-2.850	-3.118		-3.301	-3.734	-2.261	-1.571	-1.574	-2.903	-1.632	-2.947	-2.513	-3.761	-3.384	-2.077	-3.137	-2.680
Singapore	-3.443	-4.147	-4.482		-3.989	-3.094	-1.947	-2.039	-2.736	-1.924	-3.875	-2.644	-3.858	-4.206	-2.454	-3.251	-3.181
Taiwan	-2.699	-2.408	-4.599	-2.807		-2.813	-2.092	-1.395	-2.915	-1.478	-2.940	-1.692	-2.791	-3.271	-2.304	-2.241	-2.552
Indonesia	-2.547	-2.785	-3.154	-2.632	-2.154		-1.865	-2.677	-2.849	-1.306	-3.437	-2.097	-2.685	-2.681	-2.464	-2.391	-2.516
Malaysia	-2.166	-1.755	-2.588	-2.200	-2.289	-2.743		-1.554	-2.700	-1.041	-2.452	-1.082	-2.436	-2.208	-2.332	-1.759	-2.084
Philippines	-1.919	-1.962	-2.107	-1.716	-1.936	-2.845	-1.428		-2.328	-0.528	-2.510	-1.195	-2.187	-1.930	-2.201	-1.691	-1.888
Thailand	-2.510	-2.417	-3.019	-2.482	-2.269	-2.916	-1.583	-2.693		-1.133	-2.866	-1.639	-2.782	-2.547	-2.397	-2.211	-2.359
China	-1.198	-0.915	-1.083	-0.292	-1.463	-0.992	-0.561	-0.210	0.094		-0.506	0.010	-0.479	-0.938	-0.417	-0.234	-0.633
India	-3.238	-3.052	-3.487	-3.263	-3.282	-2.537	-1.687	-1.879	-2.377	-0.834		-1.828	-3.569	-3.271	-2.120	-2.698	-2.586
US	-2.891	-2.576	-2.450	-2.116	-1.559	-2.037	-0.980	-1.899	-2.348	-0.720	-2.325		-4.707	-2.176	-1.816	-4.707	-2.217
EU	-3.064	-3.274	-3.270	-2.920	-2.917	-2.708	-1.425	-1.940	-2.787	-0.394	-3.062	-4.219		-3.095	-2.215	-4.219	-2.665
NIES	-3.083	-3.225	-4.518	-3.324	-3.657	-2.819	-1.863	-1.717	-2.874	-1.684	-3.261	-2.253	-3.605	-3.681	-2.318	-2.929	-2.914
ASEAN	-2.286	-2.229	-2.717	-2.258	-2.162	-2.834	-1.625	-2.308	-2.626	-1.002	-2.816	-1.503	-2.523	-2.342	-2.348	-2.013	-2.222
US&EU	-2.977	-2.925	-2.860	-2.518	-2.238	-2.372	-1.203	-1.919	-2.568	-0.557	-2.693	-4.219	-4.707	-2.635	-2.016	-4.463	-2.597
Average	-2.656	-2.621	-3.269	-2.534	-2.642	-2.616	-1.546	-1.841	-2.437	-1.187	-2.791	-1.983	-3.060	-2.837	-2.128	-2.671	-2.435

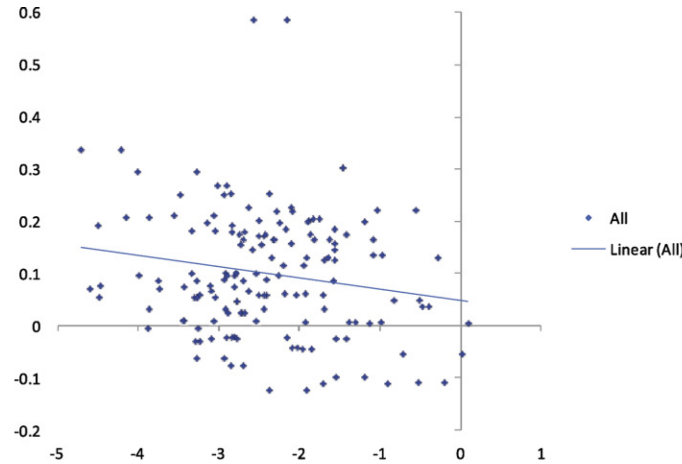
Note: $Contag^{i,j}$ measures the extent of contagion from market *j* onto market *i*.

Table 5 also shows averages of $Contag^i$ and $Contag^j$ within sub-groups NIEs, ASEAN4 and US-EU. Collectively as a region, NIEs is the most important source of risks for most Asian economies, especially other members in NIEs, and it is also the region that is most exposed to contagion originating within Asia (note the shaded areas, which mark the region with the highest *Contag*). While the US and EU are mutually exerting contagion risk onto each other, the degree of spillover to Asia is more moderate. Thus, the contagion risk appears in general to be transmitted mainly intra-regionally.[9] This is in contrast to the international risk-sharing pattern observed earlier.

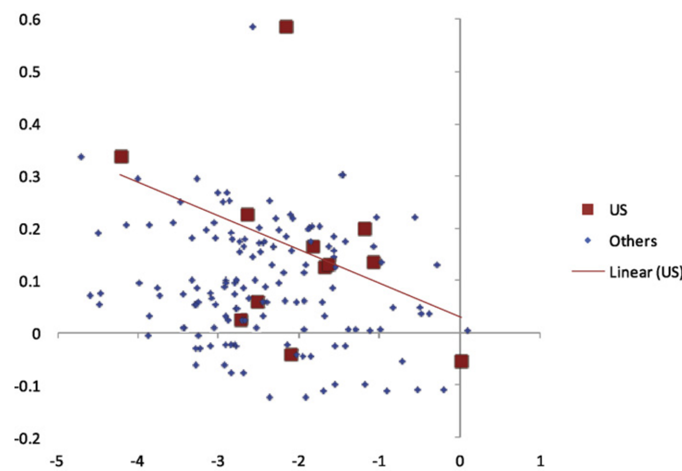
The result that NIEs, rather than the US and EU, are the main source of contagion risk for Asia is robust within various subsamples over the past decade – both $\hat{\gamma}$ and *Contag* are stable for different samples.[10] The only notable breakpoint is during the Global Financial Crisis, when ASEAN4 became the main source of tail risk for the region itself, which reinforces the extent of intra-regional spillover further. On the contrary, when we repeated the calculation over the previous decade of 1987–1999, we found that the US and EU were the main sources of tail risk for Asia during that episode. It seems to be the case that progresses over the last decade in both financial and trade integration within Asia have already shifted the source of financial contagion for Asia from external to internal. The overall results suggest that the degree to which contagion risks rise with the extent of financial integration may be shaped by a number of other factors. Closer integration between real sectors via trade channel for example can increase the tail event correlation. The relative stability of the size and pattern of these spillovers suggests that the determinant of financial contagion is largely structural and owes to an accumulative progress of globalization both in real and financial terms over a long period of time. Stalling or reversing the process of financial integration will probably do little to contain the contagion risk in the medium-term. Rather, efforts should be invested in enhancing the risk-sharing benefits obtained from financial integration.

4.2. Cost–benefit tradeoff to integration

The *BCS* and *Contag* indices are explicit measures of the benefits and costs of financial integration. The natural question is whether there exists a cost–benefit tradeoff to financial integration in the sense that reaping more benefits from integration necessarily entails greater costs in terms of higher contagion risks. In principles, a tradeoff is expected if both risk sharing and contagion risks increase with the degree of financial integration:



(a) Overall



(b) US

Fig. 2. (a and b) Risk-return tradeoff to financial integration.

if $BCS = f(integration)$ and $Contag = g(integration)$ where f and g are both increasing functions, then

$$BCS = f(g^{-1}(Contag)) \equiv F(Contag) \quad (4.6)$$

where F is a decreasing function, hence a tradeoff.[11]

To explore this issue, we do a scatter plot of *BCS* on the *y*-axis against *Contag* on the *x*-axis together with a fitted line. The result is shown in Fig. 2(a). There is a discernible tradeoff as indicated by the negatively sloped fitted line. The goodness of fit is not high ($R^2 = 0.03$), but importantly the negative slope is significant: the estimated slope is -0.02 with t-statistic of -2.21. Attaining higher risk-sharing benefit, on average, requires a higher cost in terms of contagion risk.

[9] Gebka and Serwa (2007) also found some evidence from GARCH-type analysis that intra-regional spillovers are more significant, although their sample only includes emerging equity markets.

[10] The result echoes the findings of Diebold and Yilmaz (2009) that Hong Kong and Singapore are the major economies that exert return and volatility spillovers to other Asian economies.

[11] Recent examples of a full-fledged theoretical foundation for a tradeoff between risk sharing and financial contagion include Battiston et al. (2009) which highlights the 'connectivity' aspect of integration, and Devereux and Yetman (2010a) which establishes the cost–benefit tension in a macro model with financial frictions in the form of leverage constraint.

An inspection of the terms of tradeoff for each individual case reveals a much more subtle pattern, however. In particular, consider Fig. 2(b) which overlays the original scatter plot with highlighted dots representing the US case together with an associated fitted line. This term of tradeoff lies close to the north-east bound of the scatter, suggesting that the US more or less defines the efficient cost–benefit frontier to integration for Asia. The majority of countries, in other words, are less successful than the US in taking advantage of risk-sharing opportunities, given the contagion costs incurred.

The next set of figures compare the scatter plots of other countries to the US tradeoff to highlight the differences. Fig. 3 shows that neither the EU nor Japan enjoys the same degree of risk-return efficiency of the US. Hong Kong, whose risk sharing with the US is the highest, has a tradeoff frontier that is close but still inferior to that of the US. Meanwhile, for other members of NIEs, the tradeoff lines are upward-sloping, an indication that these countries have room to benefit from integration without incurring higher costs and may have yet to reach their own efficient frontiers in integrating with the rest of Asia. Fig. 4 paints a broadly similar picture for ASEAN4, China and India, where there is also a significant potential gain from increasing risk-sharing benefits without increasing the contagion costs.

The apparent heterogeneity in the terms of tradeoffs points towards differences in the 'quality' of financial integration in Asia. When this quality differs significantly, variations in the degree of integration will not necessarily imply a positive and uniform correlation between contagion risks and risk sharing. Instead, the cost–benefit tradeoff is contextualized by the additional quality factors, or *Context*:

$$BCS = F(Contag, Context) \tag{4.7}$$

In other words, while there may be an underlying positive relationship between *BCS* and *Contag*, with movements along the relationship explained by variations in the degree of financial integration, there is also a shift variable *Context* at work and obscuring the reduced-form relationship. What is clear from Figs. 3 and 4 is that the latent factors *Context* play a role in suppressing risk sharing for some countries. One policy option to unlock the potential benefit of risk sharing is to relax these *Context*-related constraints.[12]

Our discussion will focus on four potential *Context* factors: (i) the extent of financial integration (namely, a greater quantity also leads to a higher quality of integration), (ii) the degree of financial market developments, (iii) size of economic shocks, and (iv) general macroeconomic backdrop, which are now discussed in turn.

The first factor captures the idea of a threshold effect: as countries become more financially integrated, the risk-sharing benefits increase nonlinearly. Many *Context* variables, like *Contag*, are endogenous to the extent of financial integration. Closer integration fosters development of financial products to manage and share new risks, for example there will be less need for a foreign exchange derivative market with little financial integration. Better private risk management is also encouraged by greater integration, through better liquidity as well as learning-by-doing. As a result, risk-sharing benefit may depend outright on the degree of integration, and not just through *Contag*. This linkage, if significant, lends support for further financial integration as a means to break away from the 'low integration equilibrium' and unlock the benefits of international risk sharing.[13]

Countries whose financial markets are more developed, whose access to advanced instruments such as derivatives is readily available, and whose market participants are better informed as well as more plentiful, are better equipped in dealing with idiosyncratic risks and hence should be more likely to benefit from risk sharing. But sharing risks requires a counterpart, thus an uneven development in financial market is another possible explanation for limited risk sharing in some groups of countries. To the extent that this is a binding constraint, policy efforts should focus on harmonizing market rules and practices, fostering financial market developments at a multilateral platform and developing institutions more generally. Many recent policy recommendations by the IMF and others fall within this category (see Cowen et al. (2006), FSAP reports for Asian economies, and more recently Gray et al. (2011) which discusses the progress and future directions for bond market development in ASEAN5).

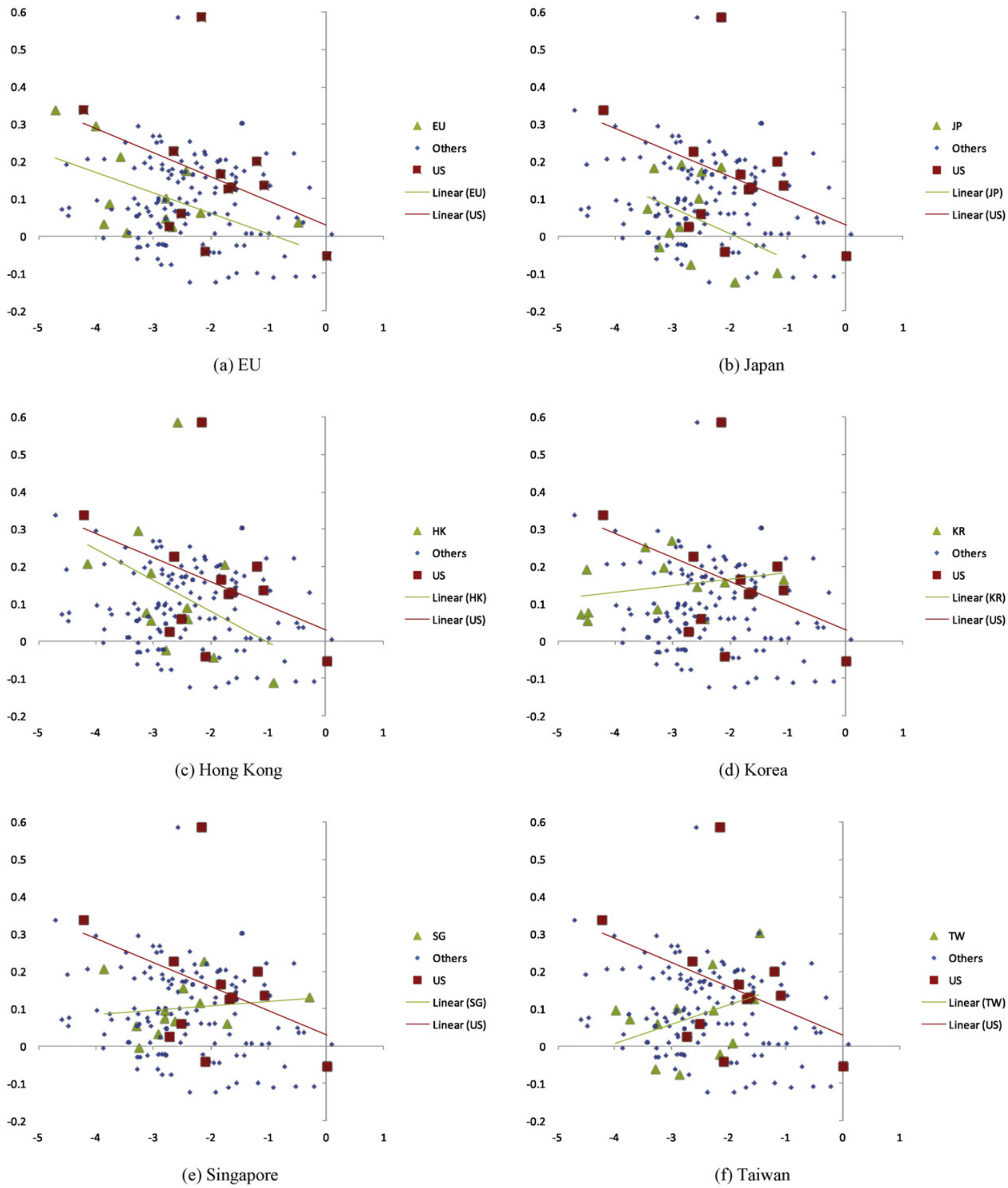
As the total amount of risks depends on the volatility of shocks, more volatility will lower *BCS* if the amount of risks being shared does not rise proportionately. Section 3 documents instances in which the estimated degree of risk sharing as measured by *BCS* indeed dropped in the period of extreme economic turbulence. We consider a stronger hypothesis, however, that a larger amount of total risks may reduce the absolute degree of risk sharing (i.e. 'Risks shared' depends negatively on shock volatility), particularly as shocks endogenously impair the ability of financial markets to allocate risks efficiently.[14] In this case, countries should step up their efforts to cooperatively smooth out shocks within the region, recognizing the limitations of financial markets in insuring against extremely large risks.

Macroeconomic environment in general may also help explain the differentiated degrees of risk sharing. Different macroeconomic backdrops imply unbalanced dynamics and propagation of shocks, with in turn can affect the financial market's ability to allocate risks across economies. Choices of monetary policy frameworks, degrees of openness, and competitiveness all contribute to heterogeneous macroeconomic conditions. There is again little scope for unilateral policy in this case. A multilateral approach to promoting risk sharing, on the

[12] A number of studies have stressed the importance of context as an important determinant of the beneficial effects of financial integration. See Prasad et al. (2003) and Masten et al. (2008).

[13] A related argument is that more open and integrated economies can better withstand economic volatility and may even be able to generate more productivity gains. See Kose et al. (2009) and references therein.

[14] In models with strong financial accelerator or cascade mechanisms, this negative dependence is not only theoretically possible but is likely. See Stiglitz (2010b).



(a) EU (b) Japan

(c) Hong Kong (d) Korea

(e) Singapore (f) Taiwan

Fig. 3. (a–f) Cost–benefit tradeoffs: EU, Japan and NIEs.

other hand, involves steps to harmonize the policy frameworks, ranging from a common recognition of broad policy priority to a stronger form culminating in an adoption of a common currency area as suggested by Mundell (1973) for example.[15]

How quantitatively relevant are these four factors? In the next section, we propose a simple reduced-form empirical strategy to address this question. Our approach is to exploit as much as possible the variation in the risk-sharing measures both

[15] Mundell (1973) argued that one important benefit of a common currency area is better international risk sharing, since having a common price level will *"...allow the country* [hit by a negative income shock] *to run down its currency holdings and cushion the impact of the loss, drawing on the resources of the other country until the cost of adjustment has been efficiently spread over the future."*

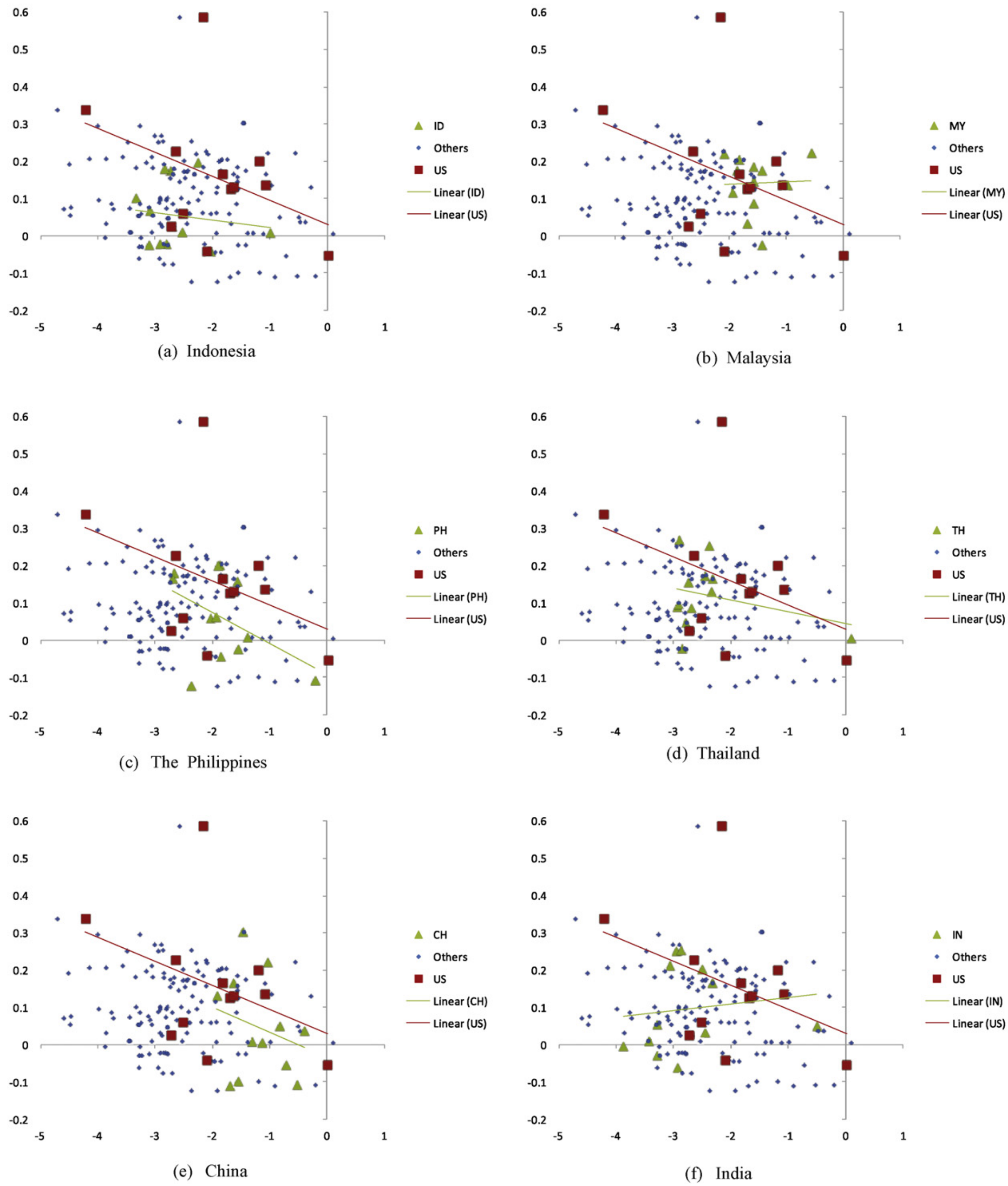


Fig. 4. (a–f) Cost–benefit tradeoffs: ASEAN4, China and India.

cross-sectionally and across time, and relate it to differences in the determining factors.

5. Making financial integration works for Asia

One salient feature of the *BCS* estimates obtained in Section 3 is the pattern of intra-regional risk sharing which varies across different groups and periods. We leverage on this variation to identify the relative importance of all the factors. For example, if financial market development was an important determinant of risk sharing, then those regions with more uneven financial development in certain period should have less intra-regional risk sharing over that particular period. Similarly, more uneven shocks or greater differences in macroeconomic environments in the cross-section should help explain more limited intra-regional risk sharing in any period. Meanwhile, a higher degree of intra-regional integration should lead to more risk sharing within the region, other things being equal.

To test these hypotheses, we consider three groups of countries: NIEs, ASEAN4 and US&EU. The dependent variable is the degree of intra-regional risk sharing within each of these three regions. *BCS* is unfortunately a poor measure for our purpose, as it must be defined over some time interval, which reduces the availability of time-series data. We therefore introduce an alternative definition of intra-regional risk sharing. For each group $j \in \{NIEs, ASEAN4, US\,\&\,EU\}$, we define $\sigma_{jt}(m)$ to be the log of cross-sectional standard deviation of log M_t^i across $i \in j$ for fixed t. $\sigma_{jt}(m)$ is a measure of intra-regional risk sharing within region j, and is different from *BCS* since it is an absolute measure and a complete time series (hence more data points for estimation).

The measure of intra-regional financial integration is taken from the Coordinated Portfolio Investment Survey (CPIS) dataset and defined to be the average proportion of portfolio investment liabilities corresponding to creditors within the same region. A larger ratio therefore indicates closer intra-regional financial integration. The data are annual and available from 2001 to 2009. For data congruency, we assume the ratios in 2000 to be the same as 2001, and 2010 the same as 2009, respectively. We then use quadratic interpolation to convert the data into monthly frequency. Denote these ratios by int_{jt}.

The extent of unbalanced financial developments is captured by the log of cross-sectional standard deviations in the ratios of stock market capitalization to nominal GDP at each date t, denoted by $\sigma_{jt}(st\_gdp)$. According to our hypothesis, $\sigma_{jt}(st\_gdp)$ should have a positive impact on $\sigma_{jt}(m)$, as more uneven development puts a drag on the ability of financial market to insure risks. There are admittedly many other measures of financial development, but their data availability is a limitation and interpretation is not necessarily less problematic.

As a proxy for size of shocks, we define $\sigma_{jt}(ip)$ to be the log of cross-sectional standard deviations at each date t of HP-filtered year-on-year growth in industrial production across each i in j. Larger $\sigma_{jt}(ip)$ indicates a larger amount of real risks within region j that can potentially be shared.

The differences in general macroeconomic conditions is measured by the log of cross-sectional standard deviations in the year-on-year core inflation, denoted by $\sigma_{jt}(\pi)$. This variable captures in a simple way the effects of monetary policy regimes, sensitivity to commodity prices and imported inflation, as well as relative position on the Phillips curve among others. The specification to be estimated is

$$\sigma_{jt}(m) = \alpha + \beta_1 int_{jt} + \beta_2 \sigma_{jt}(st\_gdp) + \beta_3 \sigma_{jt}(ip) + \beta_4 \sigma_{jt}(\pi) + \eta_j + \varepsilon_{jt} \tag{5.1}$$

where η_j denotes unobserved region-specific time-invariant effect. Note that the specification does not explicitly condition on contagion risks, because a time-series measure of contagion is not available. The implicit dependence on contagion risks will instead be picked up by int_{jt} and η_j, which in turn will affect the interpretation of β_1. We estimate OLS (ignoring η_j), fixed effects and random effects, respectively. The results are reported in Table 6.

Table 6
Determinants of intra-regional risk sharing.

	OLS	Fixed effects	Random effects
int_{jt}	−0.023	−0.156	−0.041
	(0.008)***	(0.052)***	(0.018)***
$\sigma_{jt}(st\_gdp)$	0.029	0.042	−0.062
	(0.139)	(0.101)	
$\sigma_{jt}(ip)$	0.224	0.217	0.216
	(0.066)***	(0.066)***	(0.066)***
$\sigma_{jt}(\pi)$	0.142	0.145	0.138
	(0.074)**	(0.073)***	(0.074)**
Constant	−1.275	0.316	−1.114
	(0.152)***	(0.286)***	
R^2	0.26	0.27	0.07
N	408	408	408

Standard errors are in parentheses. *** and ** indicate statistical significance at 1% and 5% respectively. Random effects estimation uses Wallace–Hussain method to compute component variances.

Except for $\sigma_{jt}(st\_gdp)$, the effects of all variables are statistically significant with signs that conform with the hypotheses for all three estimation methods. Risk sharing benefits are greater in periods and regions with tighter financial integration, less uneven economic shocks and more similar inflation rates.

More financial integration raises the risk sharing benefit, but this effect can arise both directly and indirectly through higher contagion risks. Differentiating the right hand side of equation (4.7), the total impact of integration on risk sharing can be decomposed into two parts:

$$F_1 \frac{\mathrm{d}\,Contag}{\mathrm{d}\,int} + \frac{\mathrm{d}\,F}{\mathrm{d}\,int} \tag{5.2}$$

The first term is the 'movement-along-the-curve' effect of financial integration, where risk sharing is increased at the expense of higher contagion risks. The second term is the 'shift' effect, where integration improves the terms of tradeoff via the aforementioned threshold effect. The first term has a negative sign, given our assumption that contagion risks rise with financial integration ($\mathrm{d}\,Contag/\mathrm{d}\,int > 0$) and that there exists an efficient cost–benefit tradeoff ($F_1 < 0$). Therefore our estimate of β_1, which measures the net effect of integration on risk sharing, indicates that the second term dominates in size. Controlling for fixed effects, which pick up the exogenous parts of contagion risks not explained by the degree of integration, the dominance of the shift effect is even more evident (0.156 compared to 0.023 in the OLS case). The results therefore show that there are both movement and shift effects taking place as the degree of integration rises, but there are net increases in risk sharing. Despite this sizable net gain in risk sharing benefit associated with an outward shift in the tradeoff line, the welfare implications remain unclear however, because contagion risks are forced to go up along with risk sharing. It is still possible for welfare to decrease with the degree of integration, if the welfare function is highly sensitive to financial contagion.

The importance of macroeconomic context is confirmed by the estimates. Both cyclical shocks and inflation differentials have the potential to affect the degree of international risk sharing, for any given level of contagion risks. It is worth noting that, since the dependent variable is an absolute measure of risk sharing, the dispersion in economic activity has an impact on risk sharing in absolute terms (i.e. it affects the amount of risks being shared) and not just in relative terms (percentage of risks shared, as in *BCS*). This result is consistent with the hypothesis that more volatile economic shocks can impair the risk-sharing mechanism. An implication is that risk sharing should not be thought of as an insurance mechanism against catastrophic events. Its benefit is reaped only slowly over time in an environment with relatively moderate volatility.

Another policy implication is that the role of macroeconomic policy management should go beyond the traditional one of unilateral discretion, since there is an element of externalities: when a country follows a certain path of stabilization policy or adopts a certain level of inflation target, the decisions affect the risk-sharing benefits enjoyed not only by itself but also by its neighbors. Continuing policy dialogue and coordination can help internalize these externalities and improve the sharing of risks. For example, an acknowledgement of common shocks to the region and a broad agreement of appropriate policy response to address the shocks can have beneficial indirect effects on international risk sharing.

The effect of $\sigma_{jt}(st\_gdp)$ is found to be insignificant, which may owe in part to the sample size being to small to pin down the effect of a relatively stable structural variable. $\sigma_{jt}(st\_gdp)$ varies relatively little over time in the sample, making the identification of its effect over business cycle frequency difficult. Meanwhile the cross-sectional variation of $\sigma_{jt}(st\_gdp)$ alone can only contribute so much in a very small panel such as ours. There are also many dimensions to financial development than captured by stock market capitalization to GDP. It may therefore be premature to reject the role of financial development in fostering risk sharing, in light of both estimation and measurement issues. Estimates of other parameters are robust to dropping $\sigma_{jt}(st\_gdp)$ from the specification, however.

Overall, the results show that there are indeed contextual factors capable of explaining the heterogeneous tradeoffs between risk sharing and contagion risks. Policies aimed at influencing these factors can help to enhance the quality of regional financial integration and improve the terms of tradeoffs for Asia. The fact that one significant factor, real shocks, fluctuates at the business cycle frequency points towards the role of shorter-term policy in supporting risk sharing, in addition to structural infrastructure-based development policy that is often proposed. The significance of inflation differentials suggests that more uniform policy framework can help improve risk sharing by inducing more similar macroeconomic dynamics and conditions. Meanwhile, the threshold effect of financial integration is found to be important, hence *more* integration can lead to *better* quality of integration. The net effect on welfare is however made ambiguous by endogenous contagion, rendering the policy implications less clear-cut.

6. Conclusion

Using a novel measure based on an affine term structure model, risk sharing in Asia is found to be low intra-regionally. The sharing of risks is far from perfect, and on a bilateral basis, Asian economies on average share more risk with the US and EU than among themselves. The degree of risk sharing generally fluctuates meaningfully over time unlike the downside financial contagion risks, which are more stable for any country pair according to our CoVaR-type estimates. There appears to be on average a tradeoff between risk sharing and contagion risks, suggesting that the degree of integration is a common driver of the two. However, this average tradeoff is hardly a good representative of individual Asian economies, and there is a large difference in the terms of tradeoffs across countries. The US stands out as the one that reaps the most benefit from sharing risks with Asia, for a given degree of contagion risk exposure. The heterogeneity in these tradeoffs can partly be explained by the degree of financial integration via threshold effects, as well as differences in the size of economic shocks and macroeconomic conditions.

The findings underline the need for Asian economies to enhance the quality of financial integration within the region. In other words, there is room for an appropriate policy to promote the degree of risk sharing without exposing countries to greater contagion risks. Pursuing these regional policy avenues should receive a priority over a push for further overall financial integration whose welfare effect may be ambiguous according to our findings.

Our results lend support to policy measures that address the qualitative aspect of financial integration. Development of institutional investor base, through an expanded role of pension funds, insurance industry, and asset management funds can help strengthen the regional financial market and its risk-sharing function. An expansion of derivative markets and creation of financial products will provide additional risk management capability that directly helps increase risk sharing, as well as improve market liquidity in traditional risky assets more generally. Harmonization of rules and practices, whether in terms of regulations or tax treatments, can facilitate the creation of Asia-wide portfolio investments and strengthens risk sharing mechanism. Standardization of market infrastructure, for example through linkages of settlement systems, can similarly be useful. For details of policy proposals along these lines, see IMF (2006) and Gray et al. (2011).

One possible issue for future research is an exploration of contagion and its determinants, on which this paper has little to say. Contagion risks in this paper are modeled as the extent of spillover effect conditional on an exogenous event taking place outside the domestic financial market. But a tail event such as a financial crisis is a dynamic phenomenon. Thus its unconditional probability of occurrence is likely to vary over time, if only its mechanism can be better understood. Financial contagion can also be reinforced by feedback effects, as spillovers work both ways. A better understanding of these mechanisms will enhance our understanding of the risk side of financial integration. As far as policy is concerned, the findings in this paper are entirely consistent with prudential measures targeted at curbing the degree of systemic risks. Indeed one way of improving the terms of tradeoffs would be to reduce the spillover risks, without sacrificing the risk-sharing gain. Policy efforts along both lines will complement each other towards a common goal in making financial integration work better for Asia.

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Appendix A. Data

Zero-coupon yields

The data for zero-coupon yields are end-of-month series taken from Bloomberg. The construction methodology is bootstrapping. The following is the information provided by Bloomberg.

> The zero coupon yields are derived by stripping the par coupon curve. Because zero coupon yields are derived from underlying yield curves, any changes in the underlying curve's coverage can significantly change the zero coupon values near the altered tenor. Using the set of coupon bonds, bills, swaps or a combination of these instruments, the discount factors for all tenors are derived using standard bootstrapping. The zero-coupon yields are finally calculated step-by-step using these discount factors. A minimum of four instruments at different tenors are required for each yield curve.

Stock market indices

The data for stock market indices are end-of-week series taken from Bloomberg. The following indices are used: Hang Seng (Hong Kong), KOSPI (Korea), FTSE Straits Times (Singapore), TWSE TAIEX (Taiwan), Jakarta Composite Index – JSX (Indonesia), FTSE Bursa Malaysia KLCI (Malaysia), Philippines Stock Exchange PSEi (the Philippines), SET (Thailand), Shanghai Stock Exchange Composite (China), BSE Sensex 30 (India), Dow Jones Industrial Average (US), and DAX (EU).

Others

The Coordinated Portfolio Investment Survey (CPIS) dataset is provided by the IMF at http://www.imf.org/external/np/sta/pi/cpis.htm. Stock market capitalization, nominal GDP, year-on-year changes in industrial production, and year-on-year changes in core inflation are taken from CEIC.

Appendix B. Adrian–Moench procedure

This appendix provides a brief overview of Adrian and Moench (2010) to motivate the implementation of their 3-step regression procedure. Note that the log excess return of holding an n-period bond for one period accrued at time $t+1$ can be expanded as

$$\begin{aligned} exret_{t+1}^{n-1} &\equiv p_{t+1}^{n-1} - p_t^n + p_t^1 \\ &= A_{n-1} + B'_{n-1}X_{t+1} - A_n - B'_nX_t + A_1 + B'_1X_t \\ &= A_{n-1} + B'_{n-1}(\mu + KX_t + \Sigma\varepsilon_{t+1}) - A_n - B'_nX_t + A_1 + B'_1X_t \\ &= (-A_n + A_{n-1} + B'_{n-1}\mu + A_1) + (B'_{n-1}K - B'_n + B'_1)X_t + B'_{n-1}\Sigma\varepsilon_{t+1} \end{aligned} \quad \text{(B.1)}$$

where we assume that p_t^n is affine in X_t as in Eq. (3.6). Conjecture the solution for $exret_{t+1}^{n-1}$ of the form

$$exret_{t+1}^{n-1} = B'_{n-1}\Sigma[\Lambda_0 + \Lambda_1X_t + \varepsilon_{t+1}] \quad \text{(B.2)}$$

Equating the right hand side of Eq. (B.2) to that of Eq. (B.1) and matching terms, it can easily be verified that the set of implied solutions for A_n and B'_n is identical to that of Eq. (3.7) up to the convexity terms.

This equivalence implies that the prices of risk parameters, Λ_0 and Λ_1, can be estimated by performing a 3-step regression on Eq. (B.2). First, the state equation (3.1) is estimated using OLS to get estimates for μ, K, Σ as well as the residual $\hat{\varepsilon}_{t+1}$. The second step involves performing a series of cross-sectional OLS on

$$exret_{t+1}^{n-1} = a_{n-1} + b'_{n-1}X_t + c'_{n-1}\hat{\varepsilon}_{t+1} + error \quad \text{(B.3)}$$

for all n and stacking the estimated coefficients to get $\hat{a} = [\hat{a}_1, \ldots, \hat{a}_N]$, $\hat{b} = [\hat{b}'_1, \ldots, \hat{b}'_N]'$, and $\hat{c} = [\hat{c}'_1, \ldots, \hat{c}'_N]'$. Finally, in view of Eqs. (B.2) and (B.3), estimates for Λ_0 and Λ_1 can be obtained by regressing $\hat{a}$ on $\hat{c}$ and $\hat{b}$ on $\hat{c}$, respectively

$$\begin{aligned} \hat{\Lambda}_0 &= (\hat{c}'\hat{c})^{-1}\hat{c}'\hat{a} \\ \hat{\Lambda}_1 &= (\hat{c}'\hat{c})^{-1}\hat{c}'\hat{b} \end{aligned} \quad \text{(B.4)}$$

In actual implementation, the last step is modified slightly to correct for the convexity term:

$$\hat{\Lambda}_0 = (\hat{c}'\hat{c})^{-1}\hat{c}'\left(\hat{a} + \frac{1}{2}b^*vec(\Sigma)\right) \quad \text{(B.5)}$$

where b^* is an $N \times K$ matrix with n-th row filled by $\hat{b}'_n \otimes \hat{b}'_n$, and $vec(\Sigma)$ is the vectorized Σ.

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