Supplementary Information for
Measuring the Probability of a Financial Crisis

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July 20, 2019

SI-1 Methodology to Calculate SRISK

Developed by refs (1, 2, 3, 4), SRISK is the capital that a financial firm would need to raise in order to continue to function normally if we have another financial crisis. Because it is difficult to raise capital in a financial crisis, this capital shortfall will either be met mostly by the taxpayer money or the firm will cease to function normally and may fail. For this reason, the measure is considered to be an indicator of systemic risk in much the same way as are supervisory stress tests.

Normal operation of a financial firm requires that its market capital ratio (its market value of equity divided by the sum of the book value of liabilities and the market value of equity) be above the prudential capital ratio. Let \( k \) denote this prudential ratio. The capital shortfall of a financial firm at time \( t \) can therefore be computed as:

\[
\text{Capital Shortfall}_t = k (\text{Debt}_t + \text{Equity}_t) - \text{Equity}_t
\]

SRISK is defined as the median capital shortfall conditional on a future financial crisis.

\[
\text{SRISK}_t = M_t (\text{Capital Shortfall}_{t+T|Crises_{t+T}}) = M_t (k\text{Debt}_{t+T} - (1 - k)\text{Equity}_{t+T|Crises_{t+T}})
\]

To estimate SRISK, we use a bivariate daily time series model of equity returns of the firm and of a broad market index that incorporates asymmetric volatility, time-varying correlation, and asynchronous trading. We describe this model in greater detail below. In addition, we use \( k = 8\% \) which corresponds to the typical leverage ratio of well managed financial firms in tranquil periods.\(^1\) We also make the simplifying assumption that \( \text{Debt}_t = \text{Debt}_{t+T} \) as the notional value of liabilities is not likely to change with the stress but the value of equity will.

To forecast the capital shortfall, we use a standard financial approach, the market regression, which in its simplest form can be expressed as

\[
r^f_t = \beta^f_t R^M_t + \epsilon^f_t
\]

\( r^f_t \) is the equity return on day \( t \) for firm \( f \). Similarly, \( R^M_t \) is the return on a global equity index. This relation captures the market view of the rate at which falling asset values lead to equity declines when the market collapses. It explicitly focuses on the comovement of this firm and the market, rather than just the volatility of the firm. This is why this is a macro-prudential measure of risk rather than micro-prudential.

Let \( y^M_t \) denote the equity price of the firm at the end of day \( t \) and \( P^M_t \) the market analogue. The cumulative fractional return of the firm over the horizon of \( T \) can be approximated with the same form of

\(1\)In June 2017 for example the average of the six largest US bank leverage ratios was 9.1, in June 2014 it was 11.3, in June 2010 it was 15.5, and in June 2005 it was 9.5. The average of these is 11.3 or slightly less leverage than used in SRISK. Users of V-Lab have the option of setting the capital ratio at any desired level.

\(2\)Firms using IFRS accounting rather than GAAP typically have a bigger balance sheet as there is less netting of derivatives. Consequently, we use 5.5% for all European firms.

www.pnas.org/cgi/doi/10.1073/pnas.1903879116
the 1-day-ahead forecast if the beta has almost a unit root and therefore the beta can be factored out of the sum.\(^3\)

\[
\frac{p_{t+T}^{f} - p_{t}^{f}}{p_{t}^{f}} = \exp \left( \sum_{j=1}^{T} \left( \beta_{t+j}^{f} R_{t+j}^{M} + \epsilon_{t+j}^{f} \right) \right) 
\approx \exp \left( \left( \beta_{t}^{f} \right) \left( \log \left( \frac{p_{t+T}^{M}}{p_{t}^{M}} \right) \right) \sum_{j=1}^{T} \left( \epsilon_{t+j}^{f} \right) \right) \quad (SI-2)
\]

The cumulative fractional return is itself a random variable; we consider its median value conditional on a stressed market return. Under the assumption that the idiosyncratic errors have a zero median, the median cumulative fractional return in a crisis can be expressed in the following way, where \(\theta\) corresponds to the level of stress we consider.

\[
M_{t} \left( \frac{p_{t+T}^{f} - p_{t}^{f}}{p_{t}^{f}} | \frac{p_{t+T}^{M} - p_{t}^{M}}{p_{t}^{M}} = -\theta \right) = \exp \left( \left( \beta_{t}^{f} \right) \log \left( 1 - \theta \right) \right) \quad (SI-3)
\]

We modify (SI-1) to take into account two important considerations: asynchronous trading and time-varying beta.

1. **Asynchronous trading.** The world market index we use is the MSCI ACWI Index. As this is traded in the US, the closing price is the price at the NY close, and it reflects the information that the market knows at that time. For firms located in different time zones, part of the response will appear to be from the previous day return. Hence

\[
r_{t}^{f} = \beta_{t}^{f} R_{t}^{M} + \gamma_{t}^{f} R_{t-1}^{M} + \epsilon_{t}^{f} \quad (SI-4)
\]

2. **Time-varying beta.** The Dynamic Conditional Beta (DCB) model (5) constructs a time-varying beta by allowing volatility and correlation to be time-varying with GARCH and DCC. To allow for both the constant beta and the time-varying beta flexibly, we adopt the following model:

\[
r_{t}^{f} = \left( \phi_{1} + \phi_{2} \hat{\beta}_{t}^{f} \right) R_{t}^{M} + \left( \phi_{3} + \phi_{4} \hat{\gamma}_{t}^{f} \right) R_{t-1}^{M} + \epsilon_{t}^{f} \quad (SI-5)
\]

where \(\hat{\beta}\) and \(\hat{\gamma}\) are computed from the asymmetric firm and market volatility estimates (GJR-GARCH) and a time-varying correlation estimate (DCC). The four coefficients of this model can be estimated assuming a GJR-GARCH error term.

With these two modifications, the (total) beta and SRISK of the firm are:

\[
\tilde{\beta}_{t} = \left( \phi_{1} + \phi_{2} \hat{\beta}_{t}^{f} \right) + \left( \phi_{3} + \phi_{4} \hat{\gamma}_{t}^{f} \right) 
SRISK_{t} = kDebt_{t} - (1 - k)Equity_{t} \exp \left( \tilde{\beta}_{t} \log \left( 1 - \theta \right) \right) \quad (SI-7)
\]

We consider the crisis to be six months in the future and calibrate the market stress level \(\theta\) to be 40% as the MSCI ACWI index declined approximately 40% over six months during the Global Financial Crisis. By using a one-factor stress, we reduce the possibility that we will miss the cause of the next financial crisis. Whether the crisis is caused by a housing market collapse, sovereign debt collapse, commodity price collapse, exchange rate collapse, government shut down or derivative market failure, the stock market is probably going to fall in anticipation of a decline in the real economy. It is almost inconceivable that a financial crisis could occur without a substantial fall in the stock market.

In measuring the value of debt for insurance companies, we make adjustment for separate accounts. Separate accounts are variable annuities and other investments made by insurance clients which are shown both as assets and liabilities of the firm. Consequently, fluctuations in value do not affect the book equity of the firm but they do affect the size of the balance sheet. Insurance companies often argue that the separate accounts assets and liabilities should be excluded for calculating the capital ratio as they do not really

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\(^3\)An alternative simulation approach to forecast the cumulative firm return (3, 4) has been implemented in V-Lab’s MESSIM.
benefits despite rapid growth in separate accounts. In December 2015, the median leverage among 12 U.S. life insurers was 8.1 excluding separate accounts entirely and 16.4 including them. In assessing the impact of separate accounts, we settle on a partial exclusion of separate accounts in both assets and liabilities due to the penalty associated with early withdrawal and the complicated guarantee structure.\footnote{Although the separate accounts assets belong to the investors rather than the insurance companies, many separate accounts contain explicit guarantees of return, cumulative return, distribution, and other features. Under GAAP, firms are required to report the value of these guarantees as “future policy benefits.” These are estimated based on values of derivatives and hedges and management judgment. Data from SNL Financial show that future policy benefits are roughly two-thirds of total separate accounts for the large US insurance companies. There are reasons to be concerned about the accuracy of these estimates of future policy benefits, (see 6, 7). That future policy benefits are estimated at the current time rather than at stressed times is relevant for our analysis. Under a stress scenario it is natural that the liabilities would increase. Empirically these appear not to have increased during the financial crisis even though the value of the separate accounts fell substantially. For some companies there is a remarkable stability of these future policy benefits despite rapid growth in separate accounts.}

It can be compared with SRISK under some simplifying assumptions. Suppose at time \( t \) the joint distribution of returns of one firm and the broad market is conditionally normal and expressed as:

\[
\begin{pmatrix} R_{i,t} \\ R_{m,t} \end{pmatrix} | F_{t-1} \sim N \left( 0, \begin{pmatrix} \sigma_{i,t}^2 & \rho_{i,m,t} \sigma_{i,t} \sigma_{m,t} \\ \rho_{i,m,t} \sigma_{i,t} \sigma_{m,t} & \sigma_{m,t}^2 \end{pmatrix} \right)
\] (SI-8)

Following the convention to express value-at-risk as a positive number, \( \text{VaR} (q) \) and \( \text{CoVaR} (q, p) \) are defined as

\[
\begin{align*}
\Pr_{t-1} \left( R_{i,t} < -\text{VaR}_{i,t}^q \right) &= q \\
\Pr_{t-1} \left( R_{m,t} < -\text{VaR}_{m,t}^q \right) &= q \\
\Pr_{t-1} \left( R_{m,t} < -\text{CoVaR}_{i,t}^q, R_{i,t} = -\text{VaR}_{i,t}^q \right) &= q
\end{align*}
\]

and the contribution to systemic risk, which measures the increased risk to the system when one firm is at its extreme, is called,

\[
\Delta \text{CoVaR}_{i,t} = \text{CoVaR}_{i,t}^q - \text{CoVaR}_{i,t}^{0.5}
\] (SI-9)

Evaluating (SI-9) under (SI-8) yields the simple closed form expression

\[
\Delta \text{CoVaR}_{i,t} = \rho_{i,m,t} \sigma_{m,t} \Phi^{-1} (q)
\] (SI-10)

where \( \Phi^{-1} \) is the inverse function of the standard normal cdf.

Evaluating the median firm return in a stress scenario under the same assumptions gives:

\[
M_{t-1} \left( R_{i,t} | R_{m,t} = c \right) = \frac{c}{\sigma_{m,t}}
\] (SI-11)
Conceptually, the key difference between this expression and CoVaR is that both the firm’s own volatility and its correlation with the market enter this expression whereas only the correlation affects CoVaR. This difference stems from the difference in the conditioning set between these two measures. The Exposure CoVaR measure, which reverses the conditioning and gets the same result as the median firm return in a stress scenario. In addition, CoVaR measures are also not explicitly sensitive to size or leverage, while SRISK is constructed to capture these features.

SI-2 Specification Tests and Additional Regression Results

We explain the cross-section and time-series of the Romer-Romer crisis severity measure with three scaled versions of SRISK that each corresponds to a different deleveraging strategy – SRISK/GDP for government bailout, SRISK/MV for equity issuance, and SRISK/(TA*k) for asset sales.

The first model is a panel regression of this crisis measure on the three SRISK measures including time and country fixed effects. In Table SI-1 the first column shows that the most useful variables are SRISK/(TA*k) and SRISK/MV as the measure divided by GDP is negative. The negative sign could be due to regulatory forbearance when the costs of a bailout are very high. When regulators exercise “regulatory forbearance” and don’t force the deleveraging to begin, they could delay a crisis although possibly making it more serious when it happens.

| Dep Var: CRISIS | (1) | (2) | (3) | (4) | (5) |
|-----------------|-----|-----|-----|-----|-----|
| SRISK/(TA*k)    | 5.494*** | 4.253*** | 3.808*** | 3.797*** | 5.309*** |
|                 | (0.693)  | (0.750)  | (0.745)  | (0.705)  | (0.750)  |
| SRISK/GDP       | -0.228*** | -0.278*** | -0.297*** | -0.291*** | -0.279*** |
|                 | (0.053)  | (0.058)  | (0.059)  | (0.058)  | (0.061)  |
| SRISK/MV        | 0.457**  | 0.480**  | 0.707*** | 0.594*** | 0.724*** |
|                 | (0.207)  | (0.230)  | (0.227)  | (0.224)  | (0.234)  |
| World SRISK/(TA*k) | -8.803*  | 6.058*** |          |
|                 | (4.557)  | (0.993)  |          |
| World SRISK/GDP | 13.370   |           |          |
|                 | (20.709) |           |          |
| World SRISK/MV  | 10.866*** | 5.518***  |          |
|                 | (2.617)  | (0.776)  |          |
| World log SRISK |           |           | 0.373*** |
|                 |          |           | (0.133)  |
| Time FE         | Yes     | No       | No     | No     | No     |
| Country FE      | Yes     | Yes      | Yes    | Yes    | Yes    |
| Within Country R² | 0.611  | 0.493    | 0.477  | 0.489  | 0.449  |
|                 | 0.652   | 0.547    | 0.532  | 0.543  | 0.481  |
| Observations    | 564     | 564      | 564    | 564    | 564    |

This table reports the OLS estimates of how systemic risk measures are contemporaneously associated with crisis severity. The sample includes all countries studied by (9) with the exception of Iceland from the second half of 2000 to the second half of 2012. The unit of observation is country-halfyear. The country fixed effects are included in all specifications. Standard errors are reported in parentheses. ***, **, and * represent 1%, 5%, and 10% significance, respectively.
The remaining columns replace the time fixed effects with various measures of world capital shortfall. The results are similar to the fixed effects model and show that some measure of world SRISK is correlated with the time fixed effects.

Running the same regression as a predictive regression (Table SI-2) reinforces this conclusion. With a lagged dependent variable and fixed effects, SRISK/(TA*k) remains significant. However, with measures of world SRISK, its significance is reduced.

Table SI-2: Predictive power of systemic risk measures

|                        | Dep Var: CRISIS       |
|------------------------|-----------------------|
|                        | (1)                   |
| L.CRISIS               | 0.789***              |
|                        | (0.031)               |
| L.SRISK/(TA*k)         | 1.369***              |
|                        | (0.425)               |
| L.World SRISK/(TA*k)   | -0.805                |
|                        | (0.837)               |
| L.World SRISK/MV       | -2.188***             |
|                        | (0.664)               |
| L.World log SRISK      | 0.296***              |
|                        | (0.104)               |

|                        | (2)                   |
| L.CRISIS               | 0.844***              |
|                        | (0.035)               |
| L.SRISK/(TA*k)         | 0.262                 |
|                        | (0.500)               |
| L.World SRISK/(TA*k)   | -0.794                |
|                        | (0.482)               |

|                        | (3)                   |
| L.CRISIS               | 0.871***              |
|                        | (0.035)               |
| L.SRISK/(TA*k)         | 0.856*                |
|                        | (0.479)               |
| L.World SRISK/(TA*k)   | -0.794                |
|                        | (0.482)               |

|                        | (4)                   |
| L.CRISIS               | 0.825***              |
|                        | (0.033)               |
| L.SRISK/(TA*k)         | -0.794                |
|                        | (0.482)               |
| L.World SRISK/(TA*k)   | -0.794                |
|                        | (0.482)               |

| Time FE                | Yes                   |
| Country FE             | Yes                   |
| Within Country R^2     | 0.815                 |
| Overall R^2            | 0.836                 |
| Observations           | 541                   |

This table reports the OLS estimates of how systemic risk measures predict crisis severity. The sample includes all countries studied by (9) with the exception of Iceland from the second half of 2000 to the second half of 2012. The sample size decreases relative to Table SI-1 due to the use of lagged variables. The unit of observation is country-halfyear. The country fixed effects are included in all specifications. Standard errors are reported in parentheses. ***, **, and * represent 1%, 5%, and 10% significance, respectively.

The regression does not take account of the fact that more than half of the observations have a zero value for the dependent variable. The economic reason is that a financial crisis represents a left tail event for the economy. Any measure of financial crisis severity does not distinguish strong and borderline economic conditions apart as long as a crisis has not started yet. Therefore, such a measure represents a truncated indicator of economic condition. The relationship between crisis severity and SRISK is naturally a hockey stick rather than a straight line. The Tobit which recognizes that the dependent variable is truncated at zero is the preferred estimator.

A Tobit model is defined in terms of a latent variable y_l which depends upon explanatory variables X and a disturbance. The observed dependent variable, y, is a truncated version of y_l. Under the assumption that the error term follows a standard normal distribution, the model can be expressed by two equations as follows:

\[ y = \begin{cases} 
  y_l & \text{if } y_l > 0 \\
  0 & \text{otherwise} 
\end{cases} \]

\[ y_l = X\beta + \sigma \epsilon, \ \epsilon \sim \mathcal{N}(0,1) \]

We estimate the Tobit model with country fixed effects to allow the possibility that countries will differ in the tolerable level of SRISK. This may be due to institutional markets for selling assets and pools of
investors who might be willing to step in even as a crisis is approaching. It may also be due to differences in the likelihood of a government rescue that would protect both financial firms and those buying assets.

We consider a domestic model that only uses country-level SRISK variables to explain crisis severity and a global model that expands the set of explanatory variables with world SRISK variables. The motivation of the global model comes from the observed co-movement in crisis severity across countries in Figure SI-1 and the correlation between world SRISK variables and the estimated time fixed effects in Table SI-1. To better capture the externality aspect of financial crises, we modify how these world variables are constructed. For each country, the world SRISK variables are calculated using the sum of the respective country-level variables across all other countries, which we refer to as leave-out-sums. This modification also facilitates the SRISK capacity measure developed later.

The estimation results are reported in Table SI-3. The SRISK/(TA*k) variable is highly significant in either the domestic model or the global model. Columns (1) and (2) are the specifications with the best Schwarz criterion among many specifications including many not reported here for the domestic and global models, respectively.

Estimates of country fixed effects, omitted from Table SI-3 for brevity, are tabulated in Table SI-4. For the global model, the fixed effects reflect individual countries’ resistance to a crisis with equal values of SRISK. These range from -17.9 for Belgium to -5.4 for Turkey. Thus, with equal characteristics, Turkey is much more likely to have a crisis than Belgium. Interestingly, Japan is in the middle at -10.1.
Table SI-3: Crisis severity and systemic risk measures (Tobit)

|                      | Dep Var: CRISIS |       |       |       |
|----------------------|-----------------|-------|-------|-------|
|                      | (1)            | (2)   | (3)   | (4)   |
| SRISK/(TA*k)         | 18.325***      | 13.165*** | 12.872*** | 15.467*** |
|                      | (1.213)        | (1.366) | (1.311) | (1.385) |
| D.SRISK/(TA*k)       | 6.592***       | 3.958**  |       |       |
|                      | (1.931)        | (1.874) |       |       |
| World SRISK/(TA*k)   | 14.249***      |       |       |       |
|                      | (2.387)        |       |       |       |
| D.World SRISK/(TA*k) | 7.987***       |       |       |       |
|                      | (2.759)        |       |       |       |
| World SRISK/MV       | 10.128***      |       |       |       |
|                      | (1.576)        |       |       |       |
| World log SRISK      | 1.855***       |       |       |       |
|                      | (0.360)        |       |       |       |
| D.World log SRISK    | 3.988***       |       |       |       |
|                      | (0.977)        |       |       |       |
| var(e.CRISIS)        | 11.102***      | 9.852*** | 9.829*** | 10.573*** |
|                      | (1.263)        | (1.110) | (1.109) | (1.197) |
| Country FE           | Yes            | Yes    | Yes   | Yes   |
| Pseudo $R^2$         | 0.261          | 0.291  | 0.287 | 0.283 |
| Observations         | 561            | 561    | 561   | 561   |

This table reports the Tobit estimates of how systemic risk measures are contemporaneously associated with crisis severity. The sample includes all countries studied by (9) with the exception of Iceland from the second half of 2000 to the second half of 2012. The unit of observation is country-halfyear. The world SRISK variables are calculated using leave-one-out sums of respective SRISK variables. The country fixed effects are included in all specifications. Standard errors are reported in parentheses. ***, **, and * represent 1%, 5%, and 10% significance, respectively.
| Country      | Dep Var: CRISIS | (1)  | (2)  | (3)  | (4)  |
|-------------|-----------------|------|------|------|------|
| Australia   | -7.950***       | -12.812*** | -10.118*** | -34.752*** |
|             | (1.406)         | (1.655) | (1.454) | (5.405) |
| Austria     | -7.261***       | -10.436*** | -7.943*** | -32.844*** |
|             | (0.991)         | (1.152) | (0.978) | (5.066) |
| Belgium     | -15.849***      | -17.913*** | -15.321*** | -41.048*** |
|             | (1.555)         | (1.590) | (1.503) | (5.154) |
| Canada      | -5.634***       | -10.000*** | -7.367*** | -32.027*** |
|             | (0.996)         | (1.287) | (1.047) | (5.229) |
| Denmark     | -10.622***      | -13.378*** | -10.695*** | -36.355*** |
|             | (1.236)         | (1.336) | (1.191) | (5.127) |
| Finland     | -6.365***       | -10.960*** | -8.588*** | -32.832*** |
|             | (1.175)         | (1.499) | (1.284) | (5.350) |
| France      | -11.727***      | -13.364*** | -10.736*** | -36.680*** |
|             | (1.170)         | (1.207) | (1.112) | (4.957) |
| Germany     | -11.640***      | -13.317*** | -10.677*** | -36.580*** |
|             | (1.131)         | (1.171) | (1.080) | (4.928) |
| Greece      | -5.175***       | -8.367*** | -5.990*** | -30.906*** |
|             | (1.111)         | (1.231) | (1.051) | (5.161) |
| Ireland     | -7.774***       | -10.441*** | -7.816*** | -33.462*** |
|             | (1.119)         | (1.205) | (1.058) | (5.077) |
| Italy       | -5.670***       | -8.902*** | -6.372*** | -31.476*** |
|             | (0.997)         | (1.157) | (0.963) | (5.110) |
| Japan       | -8.699***       | -10.125*** | -7.749*** | -32.984*** |
|             | (1.012)         | (1.013) | (0.949) | (4.771) |
| Luxembourg  | -9.918***       | -13.308*** | -10.740*** | -35.972*** |
|             | (1.299)         | (1.415) | (1.254) | (5.231) |
| Netherlands | -14.455***      | -16.393*** | -13.738*** | -39.603*** |
|             | (1.371)         | (1.419) | (1.314) | (5.076) |
| New Zealand | 0.366           | -5.285*** | -2.647**  | -27.204*** |
|             | (0.940)         | (1.306) | (1.029) | (5.369) |
| Norway      | -7.903***       | -11.441*** | -8.872*** | -34.021*** |
|             | (1.157)         | (1.320) | (1.133) | (5.214) |
| Portugal    | -3.938***       | -7.358*** | -4.922*** | -29.841*** |
|             | (0.992)         | (1.167) | (0.960) | (5.148) |
| Spain       | -3.827***       | -7.622*** | -5.159*** | -29.906*** |
|             | (0.938)         | (1.169) | (0.942) | (5.168) |
| Sweden      | -9.151***       | -12.416*** | -9.772*** | -35.051*** |
|             | (1.129)         | (1.296) | (1.120) | (5.152) |
| Switzerland | -10.815***      | -13.978*** | -11.282*** | -36.714*** |
|             | (1.200)         | (1.351) | (1.185) | (5.162) |
| Turkey      | -0.846          | -5.425*** | -3.039*** | -27.164*** |
|             | (0.791)         | (1.102) | (0.847) | (5.137) |
| United Kingdom | -6.423***  | -9.348*** | -6.726*** | -32.054*** |
|             | (1.028)         | (1.145) | (0.974) | (5.056) |
| United States | -4.345***   | -8.153*** | -5.595*** | -29.941*** |
|             | (0.883)         | (1.102) | (0.888) | (5.011) |

| Pseudo R²   | 0.261           | 0.291 | 0.287 | 0.283 |
| Observations| 561             | 561   | 561   | 561   |

This table reports the estimates of country fixed effects corresponding to models reported in Table SI-3. Standard errors are reported in parentheses. ***, **, and * represent 1%, 5%, and 10% significance, respectively.
The time series dynamics of world SRISK since 2000 (Figure SI-2) reveals three peaks. The magnitude of the peak is close to $4 trillion in each case and greatly exceeds the SRISK during the first seven years of this century. The first two peaks correspond to two well-known crisis episodes, the Global Financial Crisis and the European Sovereign Debt Crisis. The third peak in 2016–17 can be viewed as an Asian Debt Crisis with Japan and China as the two biggest contributors. What is common in all three episodes is that banks massively increase their holdings of perceived riskless debt and subsequently experience stress in one or at most a handful of countries, and such financial stress spreads from these countries to other countries.

The first episode, the Global Financial Crisis, is widely perceived to be tied to the housing sector which experienced a rapid increase in the five years before the crisis. The housing price boom was fueled by a rapidly growing mortgage market that employed financial engineering and securitization to fund ever declining quality of mortgages from an international pool of investment capital. The magic of CDO (collateral debt obligation) securitization was that investors and ratings agencies and regulators all regarded the senior tranches as nearly riskless, regardless of the quality of the component mortgages. As the housing price started to fall, the previously neglected risks became apparent. SRISK of all US financial firms increased from the end of 2006 to August 2008, and such an increase was most substantial for the firms that were big participants in the mortgage market. European and Asian banks also needed capital as the crisis in the US escalated. In August 2008, there are 9 European banks with SRISK higher than Lehman.

In the second episode, the US equity markets responded to the emerging Greek sovereign debt crisis with the flash crash on May 6, 2010. SRISK in Europe increased more than 30% from the low of $1,562 billion in the summer of 2009 to the peak of $2,045 billion in Jan 2012. This rise corresponded to a collapse of sovereign bond prices of several Eurozone economies, particularly the peripheral countries, Greece, Italy, Portugal, Spain, and Ireland. These bonds were regarded as riskless by investors, rating agencies, and regulators. In the early European stress tests, there was no stress considered on sovereign debt, and it continued to have zero risk weights. As many of the banks held large positions in these bonds, their equity valuation fell rapidly. As the local economies declined, the bank asset positions fell further and SRISK rose substantially. As the European financial sector deteriorated, the US continued to strengthen in part to the regulatory reform of the Dodd-Frank Act. By January 2012, the US SRISK was down to $689 billion. On the other hand, Asian SRISK continued to rise to $1,183 billion in January 2012.

As SRISK has fallen dramatically in the US and more slowly in Europe, they have been rising in Asia. Japan and China are the two biggest contributors; they have pushed the world SRISK to a level similar to the previous two peaks. The rapid growth of Japan’s SRISK from 2013 to 2017 corresponds roughly to the monetary stimulus by Prime Minister Shinzo Abe. Japanese banks hold sizable positions in Japanese Government bonds. These are discounted by financial markets leading to the large measure of undercapitalization. In China, banks are mostly state-owned, and they extend credit to state-owned enterprises and local government agencies. It is worth noting that most Japanese and Chinese banks have low betas. That is, they do not appear to be particularly risky. The substantial leverage resulting from the low market-to-book ratios is the key driver of the high SRISK. In fact, when we decompose their change in SRISK into three components—the change in debt, the change in equity, and the change in risk—we can see that the
increase in liabilities is more than 100% of the increase in SRISK with some equity increase offsetting the increase in risk. Although the mechanisms are different, both China and Japan have rapidly rising debt levels, and much of this debt is naturally viewed as riskless. In both cases, the majority of the debt is explicitly or implicitly guaranteed by the government. In neither country is there a crisis that looks like the Global Financial Crisis or the European Sovereign Debt Crisis. Both countries, however, have economic stress. Furthermore, the slowdown of the Chinese economy leads to dramatic declines in natural resource prices around the world and a commensurate increase in bank stress in natural resource-rich economies.

SI-4 Measures for Other Countries

We compute the *Probability of Crisis* and the *SRISK Capacity* from both the domestic model and the global model for all 23 countries in our sample.
Figure SI-3: Predicting Crisis - Australia

(a) Probability of Crisis (%) - Australia

(b) SRISK Capacity (USD Million) - Australia
Figure SI-4: Predicting Crisis - Austria

(a) Probability of Crisis (%) - Austria

(b) SRISK Capacity (USD Million) - Austria
Figure SI-5: **Predicting Crisis - Belgium**

(a) Probability of Crisis (%) - Belgium

(b) SRISK Capacity (USD Million) - Belgium
Figure SI-6: Predicting Crisis - Canada

(a) Probability of Crisis (%) - Canada

(b) SRISK Capacity (USD Million) - Canada
Figure SI-7: **Predicting Crisis - Denmark**

(a) Probability of Crisis (%) - Denmark

(b) SRISK Capacity (USD Million) - Denmark
Figure SI-8: Predicting Crisis - Finland

(a) Probability of Crisis (%) - Finland

(b) SRISK Capacity (USD Million) - Finland
Figure SI-9: Predicting Crisis - France

(a) Probability of Crisis (%) - France

(b) SRISK Capacity (USD Million) - France
Figure SI-10: Predicting Crisis - Germany

(a) Probability of Crisis (%) - Germany

(b) SRISK Capacity (USD Million) - Germany
Figure SI-11: Predicting Crisis - Greece

(a) Probability of Crisis (%) - Greece

(b) SRISK Capacity (USD Million) - Greece
Figure SI-12: Predicting Crisis - Ireland

(a) Probability of Crisis (%) - Ireland

(b) SRISK Capacity (USD Million) - Ireland
Figure SI-13: Predicting Crisis - Italy

(a) Probability of Crisis (%) - Italy

(b) SRISK Capacity (USD Million) - Italy
Figure SI-14: Predicting Crisis - Japan

(a) Probability of Crisis (%) - Japan

(b) SRISK Capacity (USD Million) - Japan
Figure SI-15: Predicting Crisis - Luxembourg

(a) Probability of Crisis (%) - Luxembourg

(b) SRISK Capacity (USD Million) - Luxembourg
Figure SI-16: Predicting Crisis - Netherlands

(a) Probability of Crisis (%) - Netherlands

(b) SRISK Capacity (USD Million) - Netherlands
Figure SI-17: Predicting Crisis - New Zealand

(a) Probability of Crisis (%) - New Zealand

(b) SRISK Capacity (USD Million) - New Zealand
Figure SI-18: Predicting Crisis - Norway

(a) Probability of Crisis (%) - Norway

(b) SRISK Capacity (USD Million) - Norway
Figure SI-19: Predicting Crisis - Portugal

(a) Probability of Crisis (%) - Portugal

(b) SRISK Capacity (USD Million) - Portugal
Figure SI-20: Predicting Crisis - Spain

(a) Probability of Crisis (%) - Spain

(b) SRISK Capacity (USD Million) - Spain
Figure SI-21: Predicting Crisis - Sweden

(a) Probability of Crisis (%) - Sweden

(b) SRISK Capacity (USD Million) - Sweden
Figure SI-22: Predicting Crisis - Switzerland

(a) Probability of Crisis (%) - Switzerland

(b) SRISK Capacity (USD Million) - Switzerland
Figure SI-23: Predicting Crisis - Turkey

(a) Probability of Crisis (%) - Turkey

(b) SRISK Capacity (USD Million) - Turkey
Figure SI-24: Predicting Crisis - United Kingdom

(a) Probability of Crisis (%) - United Kingdom

(b) SRISK Capacity (USD Million) - United Kingdom
Figure SI-25: Predicting Crisis - United States

(a) Probability of Crisis (%) - United States

(b) SRISK Capacity (USD Million) - United States
SI-5  Results for Parameter Stability

As a robustness check, we run a diagnostic analysis estimating the domestic and global models, excluding one country from the sample at a time. Figure SI-26 shows the point estimates and the 95% confidence intervals associated with each main regressor for the domestic model. The horizontal axis lists the country that is dropped from the sample. For instance, the first point corresponds to the estimation without Australia, and the last point corresponds to the estimation without the United States. For each regressor, we also draw a horizontal line at the value of the coefficient obtained from the full sample of 23 countries (see Column 1 of Table SI-3) for the sake of comparison. We observe that the significance of both SRISK/(TA*k) and its lag remains strong no matter which country is taken out of the sample. The magnitude of the coefficients remains stable as well. The full-sample point estimate of SRISK/(TA*k) falls in the 95% confidence interval of this variable estimated regardless of which country is dropped from estimation, so does the full-sample estimate of lagged SRISK/(TA*k).

Figure SI-26: Estimates for domestic model: Dropping one country at a time

This graph shows the stability of coefficient estimates in the domestic model by plotting the coefficients and the 95% confidence intervals estimated with one country dropped from the sample at a time. The horizontal axis lists the country that is dropped. The horizontal line in each subgraph indicates the level of the coefficient obtained from the full sample of 23 countries.

Figure SI-27 shows the analog for the global model. There are three main regressors in the global model: country-level SRISK/(TA*k), world SRISK/(TA*k), and lagged world SRISK/(TA*k). Once again, the significance of all three variables, as well as the magnitude, remains relatively unchanged no matter which country is excluded from the sample.

This approach also allows us to investigate why the SRISK/GDP variable has a negative coefficient. We estimate a diagnostic Tobit model which includes SRISK/(TA*k), SRISK/GDP, and SRISK/MV as regres-
This graph shows the stability of coefficient estimates in the global model by plotting the coefficients and the 95% confidence intervals estimated with one country dropped from the sample at a time. The horizontal axis lists the country that is dropped. The horizontal line in each subgraph indicates the level of the coefficient obtained from the full sample of 23 countries.

...
This graph shows the stability of coefficient estimates in the diagnostic Tobit model by plotting the coefficients and the 95% confidence intervals estimated with one country dropped from the sample at a time. This diagnostic model includes SRISK/(TA*k), SRISK/GDP, and SRISK/MV as regressors, as well as country fixed effects. The horizontal axis lists the country that is dropped. The horizontal line in each subgraph indicates the level of the coefficient obtained from the full sample of 23 countries.
The Diebold and Mariano Test to Assess the Impact of Tuning Parameters

Consider now the log-likelihood differential under set A of tuning parameter values relative to set B for country $i$ and time $t$

$$z_{i,t} = LL_{i,t}^A - LL_{i,t}^B$$

The null hypothesis is that the mean of log-likelihood differential $z$ is zero. In a time-series context where the DM test is originally developed, the DM statistic can be calculated by regressing the log-likelihood differential $z$ on an intercept, using heteroscedasticity and autocorrelation consistent (HAC) standard errors. In a panel data context such as ours, both the Newey-West standard errors which consider autocorrelation of the moving average type with lag length $q$ and the clustered standard errors at the level of the panel identifier are HAC. Neither of them allows for cross-sectional correlation, however. To allow for this possibility, we also calculate the Driscoll-Kraay standard errors (10) which are robust to very general forms of cross-sectional as well as temporal dependence. Loosely speaking, the Driscoll and Kraay methodology applies a Newey-West type correction to the sequence of cross-sectional averages of the moment conditions.

Both the Newey-West and the Driscoll-Kraay standard errors allow for residual correlation of the moving average type with lag length $q$. This assumption is not overly restrictive as autoregressive (AR) processes can normally be well approximated by finite order MA processes. Let $m(T)$ denote the maximum lag length up to which the residuals may be autocorrelated. (11) show that for the case of using modified Bartlett weights, their estimator is consistent if $m(T)$ increases with $T$ but at a rate slower than $T^{1/4}$. Therefore, it is not advisable to select an $m(T)$ which is close to the maximum lag length $T - 1$. We adopt the plug-in estimators (12, 13, and others). These are automated procedures that use an asymptotic mean squared error criterion to deliver the optimum lag length.

In our application, we use the following simple rule of thumb based on the Newey-West plug-in procedure (13) to determine the maximum lag length $m(T)$:

$$m(T) = \text{floor} \left[ 4 \left( \frac{T}{100} \right)^{2/9} \right]$$

We conduct the Diebold and Mariano test for testing the difference between an alternative model (model A) and the baseline model (model B) for all alternative models that have a higher (maximized) log-likelihood than the baseline model. These are seemingly better models. By construction, the DM test statistic will be positive. For the domestic model, 36 out of 209 sets of alternative tuning parameter values yield a seemingly better model. They are listed in Table SI-5 in the descending order of log-likelihood. Regardless of which HAC standard errors are used, the difference from the baseline model is insignificant for any alternative model. Therefore, we conclude that the baseline model is adequate.
## Table SI-5: Tuning parameters for the domestic model

| Stress (%) | SA incl. (%) | k1 (%) | k2 (%) | Newey-West | Clustered by country | Driscoll-Kraay |
|-----------|-------------|--------|--------|------------|----------------------|---------------|
| Model 1  | 50          | 0      | 5.5    | 5.5        | 0.799                | 0.576         | 0.832         |
| Model 2  | 50          | 20     | 5.5    | 5.5        | 0.999                | 0.544         | 0.802         |
| Model 3  | 50          | 40     | 5.5    | 5.5        | 0.749                | 0.535         | 0.775         |
| Model 4  | 45          | 0      | 5.5    | 5.5        | 0.644                | 0.515         | 0.700         |
| Model 5  | 45          | 20     | 5.5    | 5.5        | 0.643                | 0.513         | 0.699         |
| Model 6  | 45          | 40     | 5.5    | 5.5        | 0.617                | 0.490         | 0.678         |
| Model 7  | 50          | 60     | 5.5    | 5.5        | 0.686                | 0.489         | 0.715         |
| Model 8  | 45          | 60     | 5.5    | 5.5        | 0.579                | 0.457         | 0.645         |
| Model 9  | 50          | 80     | 5.5    | 5.5        | 0.620                | 0.442         | 0.651         |
| Model 10 | 45          | 80     | 5.5    | 5.5        | 0.529                | 0.415         | 0.595         |
| Model 11 | 50          | 100    | 5.5    | 5.5        | 0.559                | 0.399         | 0.590         |
| Model 12 | 45          | 100    | 5.5    | 5.5        | 0.481                | 0.376         | 0.544         |
| Model 13 | 60          | 0      | 4.0    | 4.0        | 0.269                | 0.190         | 0.305         |
| Model 14 | 60          | 20     | 4.0    | 4.0        | 0.266                | 0.188         | 0.294         |
| Model 15 | 60          | 40     | 4.0    | 4.0        | 0.236                | 0.167         | 0.259         |
| Model 16 | 45          | 0      | 8.0    | 5.5        | 0.680                | 0.472         | 0.645         |
| Model 17 | 60          | 60     | 4.0    | 4.0        | 0.194                | 0.137         | 0.211         |
| Model 18 | 45          | 20     | 8.0    | 5.5        | 0.630                | 0.439         | 0.568         |
| Model 19 | 60          | 80     | 4.0    | 4.0        | 0.152                | 0.108         | 0.164         |
| Model 20 | 55          | 0      | 5.5    | 5.5        | 0.208                | 0.140         | 0.199         |
| Model 21 | 45          | 40     | 8.0    | 5.5        | 0.465                | 0.329         | 0.403         |
| Model 22 | 55          | 20     | 5.5    | 5.5        | 0.190                | 0.128         | 0.177         |
| Model 23 | 60          | 100    | 4.0    | 4.0        | 0.107                | 0.076         | 0.115         |
| Model 24 | 55          | 40     | 5.5    | 5.5        | 0.129                | 0.088         | 0.120         |
| Model 25 | 45          | 60     | 8.0    | 5.5        | 0.244                | 0.179         | 0.209         |
| Model 26 | 40          | 0      | 5.5    | 5.5        | 0.072                | 0.059         | 0.078         |
| Model 27 | 40          | 20     | 5.5    | 5.5        | 0.070                | 0.058         | 0.076         |
| Model 28 | 40          | 40     | 5.5    | 5.5        | 0.060                | 0.050         | 0.066         |
| Model 29 | 55          | 60     | 5.5    | 5.5        | 0.064                | 0.044         | 0.060         |
| Model 30 | 40          | 0      | 8.0    | 5.5        | 0.463                | 0.537         | 0.416         |
| Model 31 | 40          | 20     | 8.0    | 5.5        | 0.484                | 0.612         | 0.438         |
| Model 32 | 40          | 60     | 5.5    | 5.5        | 0.028                | 0.023         | 0.031         |
| Model 33 | 50          | 0      | 8.0    | 5.5        | 0.030                | 0.021         | 0.027         |
| Model 34 | 45          | 80     | 8.0    | 5.5        | 0.030                | 0.023         | 0.026         |
| Model 35 | 55          | 80     | 5.5    | 5.5        | 0.007                | 0.005         | 0.007         |
| Model 36 | 40          | 80     | 5.5    | 5.5        | 0.002                | 0.002         | 0.003         |

This table reports the t-statistics for the Diebold and Mariano (DM) test comparing the domestic model obtained from an alternative set of tuning parameter values against the baseline model. We construct the DM test statistic with three types of heteroscedasticity and autocorrelation consistent (HAC) standard errors—the Newey-West, clustered by country, and the Driscoll-Kraay standard errors. In specifying the maximum lag for the residual autocorrelation for both the Newey-West and the Driscoll-Kraay standard errors, we use a heuristic based on the plug-in procedure (13). See the main text for details. We include all alternative models that have a higher (maximized) log-likelihood, which result in a positive DM test statistic by construction, here.
For the global model, 106 out of 209 sets of alternative tuning parameter values yield a seemingly better model. They are listed in Table SI-6. There is evidence that better stress tests can be found than the baseline when using the simple Newey-West standard errors but these are not significantly different when using measures which take the panel structure into account.

Table SI-6: Diebold and Mariano test for the global model

| Model | Stress (%) | SA incl. (%) | k1 (%) | k2 (%) | Newey-West | Clustered by country | Driscoll-Kraay |
|-------|------------|--------------|--------|--------|------------|---------------------|---------------|
| 1     | 60         | 0            | 4.0    | 4.0    | 2.205      | 1.538               | 1.752         |
| 2     | 60         | 20           | 4.0    | 4.0    | 2.197      | 1.527               | 1.767         |
| 3     | 60         | 40           | 4.0    | 4.0    | 2.122      | 1.467               | 1.746         |
| 4     | 50         | 0            | 5.5    | 5.5    | 2.509      | 1.658               | 1.674         |
| 5     | 55         | 0            | 5.5    | 5.5    | 2.053      | 1.342               | 1.439         |
| 6     | 50         | 20           | 5.5    | 5.5    | 2.531      | 1.652               | 1.712         |
| 7     | 55         | 20           | 5.5    | 5.5    | 2.023      | 1.314               | 1.448         |
| 8     | 60         | 60           | 4.0    | 4.0    | 2.012      | 1.382               | 1.703         |
| 9     | 50         | 40           | 5.5    | 5.5    | 2.454      | 1.581               | 1.718         |
| 10    | 55         | 40           | 5.5    | 5.5    | 1.922      | 1.243               | 1.432         |
| 11    | 60         | 80           | 4.0    | 4.0    | 1.895      | 1.293               | 1.648         |
| 12    | 50         | 60           | 5.5    | 5.5    | 2.339      | 1.489               | 1.710         |
| 13    | 45         | 0            | 5.5    | 5.5    | 2.384      | 1.704               | 1.635         |
| 14    | 60         | 0            | 5.5    | 5.5    | 1.362      | 0.907               | 1.025         |
| 15    | 55         | 60           | 5.5    | 5.5    | 1.815      | 1.168               | 1.417         |
| 16    | 45         | 20           | 5.5    | 5.5    | 2.419      | 1.707               | 1.689         |
| 17    | 60         | 100          | 4.0    | 4.0    | 1.778      | 1.205               | 1.584         |
| 18    | 60         | 20           | 5.5    | 5.5    | 1.303      | 0.866               | 1.007         |
| 19    | 50         | 80           | 5.5    | 5.5    | 2.223      | 1.400               | 1.697         |
| 20    | 55         | 80           | 5.5    | 5.5    | 1.715      | 1.096               | 1.401         |
| 21    | 55         | 0            | 4.0    | 4.0    | 1.776      | 1.257               | 1.729         |
| 22    | 45         | 40           | 5.5    | 5.5    | 2.381      | 1.655               | 1.709         |
| 23    | 55         | 20           | 4.0    | 4.0    | 1.754      | 1.232               | 1.734         |
| 24    | 55         | 100          | 5.5    | 5.5    | 1.621      | 1.029               | 1.383         |
| 25    | 50         | 100          | 5.5    | 5.5    | 2.113      | 1.314               | 1.680         |
| 26    | 60         | 40           | 5.5    | 5.5    | 1.211      | 0.803               | 0.975         |
| 27    | 45         | 60           | 5.5    | 5.5    | 2.289      | 1.560               | 1.701         |
| 28    | 55         | 40           | 4.0    | 4.0    | 1.692      | 1.182               | 1.696         |
| 29    | 60         | 60           | 5.5    | 5.5    | 1.125      | 0.743               | 0.944         |
| 30    | 55         | 60           | 4.0    | 4.0    | 1.581      | 1.094               | 1.612         |
| 31    | 45         | 80           | 5.5    | 5.5    | 2.157      | 1.444               | 1.660         |
| 32    | 60         | 80           | 5.5    | 5.5    | 1.049      | 0.690               | 0.916         |
| 33    | 45         | 100          | 5.5    | 5.5    | 2.028      | 1.333               | 1.599         |
| 34    | 55         | 80           | 4.0    | 4.0    | 1.456      | 0.997               | 1.497         |
| 35    | 60         | 100          | 5.5    | 5.5    | 0.973      | 0.637               | 0.882         |
| 36    | 55         | 100          | 4.0    | 4.0    | 1.318      | 0.895               | 1.351         |
| 37    | 40         | 0            | 5.5    | 5.5    | 1.551      | 1.271               | 1.208         |
| 38    | 55         | 0            | 8.0    | 5.5    | 1.363      | 0.984               | 1.173         |
| 39    | 40         | 20           | 5.5    | 5.5    | 1.550      | 1.261               | 1.242         |
| 40    | 40         | 40           | 5.5    | 5.5    | 1.511      | 1.221               | 1.244         |
| 41    | 50         | 0            | 8.0    | 5.5    | 1.988      | 1.433               | 1.608         |
| 42    | 55         | 20           | 8.0    | 5.5    | 1.236      | 0.898               | 1.101         |
Table SI-6: Diebold and Mariano test for the global model (continued)

| Stress (%) | SA incl. (%) | k1 (%) | k2 (%) | Newey-West | Clustered by country | Driscoll-Kraay |
|------------|--------------|--------|--------|------------|----------------------|---------------|
| Model      |              |        |        |            |                      |               |
| 43         | 50           | 20     | 8.0    | 5.5        | 1.839                | 1.344         | 1.565         |
| 44         | 40           | 60     | 5.5    | 5.5        | 1.395                | 1.116         | 1.182         |
| 45         | 60           | 0      | 8.0    | 5.5        | 0.770                | 0.557         | 0.679         |
| 46         | 55           | 40     | 8.0    | 5.5        | 1.055                | 0.769         | 0.982         |
| 47         | 40           | 80     | 5.5    | 5.5        | 1.264                | 0.993         | 1.091         |
| 48         | 50           | 40     | 8.0    | 5.5        | 1.537                | 1.133         | 1.394         |
| 49         | 60           | 20     | 8.0    | 5.5        | 0.667                | 0.483         | 0.604         |
| 50         | 55           | 60     | 8.0    | 5.5        | 0.883                | 0.645         | 0.860         |
| 51         | 45           | 0      | 8.0    | 5.5        | 2.691                | 1.916         | 1.926         |
| 52         | 50           | 0      | 4.0    | 4.0        | 0.751                | 0.527         | 0.942         |
| 53         | 40           | 100    | 5.5    | 5.5        | 1.108                | 0.855         | 0.957         |
| 54         | 50           | 60     | 8.0    | 5.5        | 1.233                | 0.914         | 1.187         |
| 55         | 50           | 20     | 4.0    | 4.0        | 0.706                | 0.493         | 0.886         |
| 56         | 45           | 20     | 8.0    | 5.5        | 2.516                | 1.810         | 1.984         |
| 57         | 60           | 40     | 8.0    | 5.5        | 0.546                | 0.396         | 0.512         |
| 58         | 55           | 80     | 8.0    | 5.5        | 0.732                | 0.534         | 0.740         |
| 59         | 35           | 0      | 8.0    | 8.0        | 0.569                | 0.395         | 0.464         |
| 60         | 50           | 40     | 4.0    | 4.0        | 0.660                | 0.459         | 0.816         |
| 61         | 40           | 0      | 8.0    | 8.0        | 0.507                | 0.344         | 0.448         |
| 62         | 35           | 20     | 8.0    | 8.0        | 0.536                | 0.367         | 0.452         |
| 63         | 30           | 0      | 8.0    | 8.0        | 0.551                | 0.398         | 0.421         |
| 64         | 40           | 20     | 8.0    | 8.0        | 0.464                | 0.311         | 0.425         |
| 65         | 55           | 100    | 8.0    | 5.5        | 0.612                | 0.446         | 0.635         |
| 66         | 45           | 40     | 8.0    | 5.5        | 2.027                | 1.485         | 1.794         |
| 67         | 50           | 80     | 8.0    | 5.5        | 0.943                | 0.701         | 0.946         |
| 68         | 30           | 20     | 8.0    | 8.0        | 0.526                | 0.375         | 0.413         |
| 69         | 60           | 60     | 8.0    | 5.5        | 0.443                | 0.321         | 0.429         |
| 70         | 50           | 60     | 4.0    | 4.0        | 0.562                | 0.390         | 0.678         |
| 71         | 45           | 0      | 8.0    | 8.0        | 0.382                | 0.253         | 0.363         |
| 72         | 35           | 40     | 8.0    | 8.0        | 0.432                | 0.293         | 0.381         |
| 73         | 45           | 20     | 8.0    | 8.0        | 0.324                | 0.213         | 0.320         |
| 74         | 60           | 80     | 8.0    | 5.5        | 0.361                | 0.262         | 0.360         |
| 75         | 40           | 40     | 8.0    | 8.0        | 0.365                | 0.244         | 0.351         |
| 76         | 30           | 40     | 8.0    | 8.0        | 0.421                | 0.297         | 0.344         |
| 77         | 50           | 100    | 8.0    | 5.5        | 0.696                | 0.517         | 0.714         |
| 78         | 50           | 80     | 4.0    | 4.0        | 0.450                | 0.310         | 0.521         |
| 79         | 45           | 60     | 8.0    | 5.5        | 1.385                | 1.031         | 1.328         |
| 80         | 60           | 100    | 8.0    | 5.5        | 0.307                | 0.222         | 0.314         |
| 81         | 35           | 60     | 8.0    | 8.0        | 0.330                | 0.222         | 0.303         |
| 82         | 35           | 0      | 5.5    | 5.5        | 0.411                | 0.356         | 0.372         |
| 83         | 40           | 60     | 8.0    | 8.0        | 0.280                | 0.186         | 0.281         |
| 84         | 45           | 40     | 8.0    | 8.0        | 0.237                | 0.156         | 0.245         |
| 85         | 50           | 0      | 8.0    | 8.0        | 0.199                | 0.130         | 0.196         |
| 86         | 35           | 20     | 5.5    | 5.5        | 0.377                | 0.326         | 0.352         |
| 87         | 50           | 100    | 4.0    | 4.0        | 0.331                | 0.226         | 0.366         |
| 88         | 30           | 60     | 8.0    | 8.0        | 0.300                | 0.210         | 0.256         |
| 89         | 35           | 40     | 5.5    | 5.5        | 0.331                | 0.286         | 0.319         |
| Model | Stress (%) | SA incl. (%) | k1 (%) | k2 (%) | Newey-West | Clustered by country | Driscoll-Kraay |
|-------|------------|--------------|--------|--------|------------|----------------------|---------------|
| 90    | 35         | 80           | 8.0    | 8.0    | 0.250      | 0.167                | 0.239         |
| 91    | 45         | 80           | 8.0    | 5.5    | 0.801      | 0.604                | 0.769         |
| 92    | 40         | 80           | 8.0    | 8.0    | 0.212      | 0.140                | 0.221         |
| 93    | 45         | 60           | 8.0    | 8.0    | 0.167      | 0.109                | 0.180         |
| 94    | 50         | 20           | 8.0    | 8.0    | 0.132      | 0.087                | 0.135         |
| 95    | 30         | 80           | 8.0    | 8.0    | 0.202      | 0.140                | 0.179         |
| 96    | 35         | 100          | 8.0    | 8.0    | 0.176      | 0.117                | 0.174         |
| 97    | 40         | 0            | 8.0    | 5.5    | 1.318      | 1.204                | 0.798         |
| 98    | 40         | 100          | 8.0    | 8.0    | 0.143      | 0.094                | 0.155         |
| 99    | 35         | 60           | 5.5    | 5.5    | 0.205      | 0.177                | 0.201         |
| 100   | 45         | 80           | 8.0    | 8.0    | 0.101      | 0.066                | 0.113         |
| 101   | 45         | 100          | 8.0    | 5.5    | 0.343      | 0.260                | 0.318         |
| 102   | 30         | 100          | 8.0    | 8.0    | 0.118      | 0.081                | 0.108         |
| 103   | 40         | 20           | 8.0    | 5.5    | 1.349      | 1.233                | 0.836         |
| 104   | 50         | 40           | 8.0    | 8.0    | 0.055      | 0.036                | 0.059         |
| 105   | 45         | 100          | 8.0    | 8.0    | 0.034      | 0.022                | 0.040         |
| 106   | 35         | 80           | 5.5    | 5.5    | 0.059      | 0.050                | 0.057         |

This table reports the t-statistics for the Diebold and Mariano (DM) test comparing the global model obtained from an alternative set of tuning parameter values against the baseline model. We construct the DM test statistic with three types of heteroscedasticity and autocorrelation consistent (HAC) standard errors—the Newey-West, clustered by country, and the Driscoll-Kraay standard errors. In specifying the maximum lag for the residual autocorrelation for both the Newey-West and the Driscoll-Kraay standard errors, we use a heuristic based on the plug-in procedure (13). See the main text for details. We include all alternative models that have a higher (maximized) log-likelihood, which result in a positive DM test statistic by construction, here.
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