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Introduction

Markus Brunnermeier and Arvind Krishnamurthy

The financial crisis of 2007 to 2008 was an urgent call for rethinking the measurement of economic activity and for developing macroeconomic models where finance plays an important role. Existing measurement systems did not reveal the fragility of the financial sector, and particularly the magnitude of its exposure to real estate risk. Mainstream macroeconomic models could not assess the impact of a meltdown of the financial sector ("systemic risk") because the financial sector typically did not play a central role in these models.

Brunnermeier, Gorton, and Krishnamurthy (2012) draw an analogy between the situation during and after the crisis and similar developments during the 1930s in the midst of the Great Depression. It was at this time that Richard Stone, Simon Kuznets, Arthur Burns, Wesley Mitchell, and their colleagues developed the first official measures of economic activity for the overall economy, that is, the National Income and Product Accounts, and the chronology of business cycles. Richard Froyen (2009, 13) put it this way:

> One reads with dismay of Presidents Hoover and then Roosevelt designing policies to combat the Great Depression of the 1930s on the basis of such sketchy data as stock prices indices, freight car loadings, and incomplete indices of industrial production. The fact was that comprehensive measures of national income and output did not exist at the time. The

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> Depression, and with it the growing role of government in the economy, emphasized the need for such measures and led to the development of a comprehensive set of national income accounts.[1]

In the fall of 2010 and the spring of 2011, the National Bureau of Economic Research (NBER) held two conferences that brought together leading academic researchers, central bankers, and other financial market experts to discuss ideas on advancing measurement and macroeconomic modeling to face these challenges. This book contains a selection of the papers that were presented at the conferences.

Existing measurement systems, such as the national income accounts and the Federal Reserve's Flow of Funds focus on measuring flows and stock variables. Recent events have highlighted the importance of measuring risks. Simply focusing on flow or stock variables is insufficient, especially in a world of derivatives that may divorce initial risk exposures and cash flows. For example, entering a futures position does not involve large cash flows initially even though both parties expose themselves to potentially large risks. Thus a theme that runs through the measurement proposals that are analyzed in this book is the importance of measuring risks to form a comprehensive "risk topography" of the economy.

A large part of macro risk is endogenously generated by the system. Systemic crises are the result of a negative shock, or trigger, affecting a fragile or vulnerable economy. While these triggers may vary from crisis to crisis, the underlying vulnerabilities have much greater commonality across episodes. The chapters in this book inform us about vulnerabilities as opposed to triggers. For example, in the context of the recent crisis, the trigger was ostensibly the bursting of a real estate bubble, while amplification occurred through a number of vulnerabilities in the financial and household sector. We have focused on the vulnerabilities in part because they are recurring phenomena across crises and thus most amenable to systematic study.

There are a variety of vulnerabilities that observers point to during financial crises. Network models capture so called "domino effects." Market participants that are linked through contractual arrangements suffer if one of their contracting partners defaults. This can trigger a whole chain reaction throughout the system. Spillovers can also occur when participants are not directly linked. For example, if many financial institutions are exposed to a given asset class, and some institutions are distressed and have to reduce their asset holdings, then asset prices may fall, triggering losses across all institutions. These types of spillovers are not limited to contractually linked institutions and are arguably more powerful in that they affect a large set of institutions. Indirect spillover effects depend crucially on the response of market participants. If most participants decide to hold on to their assets or even step in and buy more, then they act as shock absorbers. On the other

1. This quotation is also cited by Landefeld, Seskin, and Fraumeni (2008).

hand, if after an adverse shock they also sell assets and withdraw funds, they become shock amplifiers. Their response depends primarily on their liquidity mismatch, leverage, capital, and overall risk exposure. Thus, aggregated measures of these variables are likely to be important in assessing underlying vulnerabilities. The chapters in this book discuss these types of vulnerabilities as well as others involving the corporate and household sectors.

While many of the vulnerabilities discussed in the book have been pointed to in prior theoretical work, they have not been systematically measured and the question remains of how quantitatively important they are in driving macroeconomic patterns during systemic crises. Which types of vulnerabilities are more important? How do they interact? We expect that the types of measurements advanced in this book will help observers better identify significant vulnerabilities and thus serve as an early warning system for crises. We also expect that the data, as it is accumulated over time, will shape the development of macroeconomic models of systemic risk by providing the essential data on which to calibrate and discriminate across competing models. This latter point concerning the interplay between data collection and macro theory is the second theme that runs through this book. The emphasis on macro stresses that amplification, vulnerabilities, and fragility are general equilibrium phenomena.[2]

Ultimately, better measurement can also improve the regulatory framework for financial institutions. For example, without clear measures of banks' macro risk exposures and a corresponding macroeconomic model that can quantify financial stability, it is impossible to determine whether the capital requirement for banks should be, say, 7 percent or 20 percent.

The book will be of most value to those in regulatory positions who, since the crisis, have been involved in efforts to improve current measurement systems. The book is also of interest to academics that plan to conceptualize effective measurement and make future use of the collected data to discriminate across various macroeconomic models with financial frictions. The book outlines the issues that need to be addressed by a new measurement system that captures the linkage between finance and the macroeconomy. Many of the chapters explain how a given measurement can be used to further understand systemic risk and thus illustrate the potential of using measurement to inform models. The book also addresses conceptual questions: How should a policymaker think about measurement of a financial world of increasing complexity and uncertainty? What are the tradeoffs in making measured data public? In addition to conceptual measurement issues, the book offers explicit measurement strategies that can be implemented either

2. These points regarding focusing on a risk topography that can be used in a general equilibrium macro model are drawn from and expanded on in our collaboration with Gary Gorton (see Brunnermeier, Gorton, and Krishnamurthy 2012).

immediately (some of which have already been implemented following the conferences) or within a couple of years.

Following the introduction, the first chapter in this book, by Lars Peter Hansen, discusses some of the challenges that arise when measurement outpaces theory. Hansen's chapter recalls discussions from seventy years ago on national income accounting and Arthur Burns and Wesley Mitchell's (1946) well-known book on the measurement of business cycles. Tjalling Koopman's review of the Burns and Mitchell book is famous in its own right ("Measurement without Theory") and criticizes the authors for being "unbendingly empiricist," charging that their approach limits the usefulness of their measurement. The approaches taken in this book may be criticized on similar grounds. However, history has validated Burns and Mitchell's empirical approach and as Hansen notes, "an unabashedly empirical approach can most definitely be of considerable value, especially in the initial stages of a research agenda." The national income accounting measurement agenda that earned Nobel Prizes for Simon Kuznets and Richard Stone was initially guided by incomplete theories of the economy, but the measures have proven central to economists' understanding of the economy. Likewise, we see this book as offering approaches to measurement that will better our understanding of macrofinancial links.

Hansen's chapter also notes that since the measurement agenda is in its initial stages, it is important to diversify across possible approaches and also to ensure that measurements by government agencies continue to be responsive to research needs. Theories will change with new data and this will suggest the collection of other data. The Job Openings and Labor Turnover Survey (JOLTS) produced by the Bureau of Labor Statistics (BLS) provides a clear example of the interplay between theory and data collection efforts. Economists including Peter Diamond, Dale Mortensen, and Chris Pissarides have written theoretical articles on job search. These models were evaluated using data sets pieced together from data collected for other purposes by the Census Bureau and the BLS's Labor Turnover Survey. The JOLTS data was informed by the new search theory and has greatly advanced our understanding of labor markets. The resulting empirical insights then subsequently allowed researchers to better discriminate across various models.

The second chapter of the book by Augustin Landier and David Thesmar addresses the trade-offs in making data public. A common view from the private sector is that making information public can negatively affect the incentives of agents and reduce welfare. An example that is often given is that revealing data on banks' trading positions may reduce market making activity and liquidity. Banks may even be exposed to predatory trading activity. In academic debates, an argument given for suppressing information is that the release of precise public information can coordinate agent actions in a manner that is welfare reducing. For example, it can induce a bank run. On the other hand, as we have discussed, publicizing information is valuable in identifying vulnerabilities early on. In addition, it might stimulate further research on macrofinancial modeling, which can better guide regulatory policy. Landier and Thesmar discuss these and other issues in their chapter. They argue that there are three dimensions to consider when releasing information: granularity of data, frequency of data reporting, and lags in data disclosure. They consider the costs and benefits of disclosure along these dimensions. The analysis bears on questions such as: At what frequency should data be collected and made available? How long should the regulator wait before releasing the data? At what level of detail (granularity) should information be released, and if the public information is detailed, should it be made anonymous?

The remainder of the book, chapters 3 through 16, analyzes specific measurement approaches covering different sectors of the economy. We have organized these chapters into five parts. The first part includes Hansen's and Landier and Thesmar's chapters covering conceptual measurement issues. The second part concerns the measurement of risk exposures within the financial sector. The third part discusses measuring leading response indicators, such as liquidity and leverage, and other factors that may indicate vulnerability of a particular sector. The fourth part is concerned with financial intermediation and credit markets, covering both the funding and lending side of intermediaries. The fifth part tackles the household sector, whose leverage dynamics have played an important role in the real estate boom/bust. The sixth part covers the nonfinancial corporate sector and discusses data to diagnose how financial frictions may affect corporate investment. The last part discusses international issues.

The book need not be read in this order. We highlight a number of specific chapters analyzing concrete strategies for measurement that could be quickly and easily implemented. These chapters include Duffie's "10-by-10-by-10" proposal (chapter 3), McDonald's margin chapter (chapter 5), Geanakoplos and Pedersen's leverage chapter (chapter 8), Bassett et al.'s chapter on bank lending (chapter 10), and Parker's household finance "LEADS" proposal (chapter 13). Other chapters outline measurement concepts that can be implemented only over longer horizons, or step back and argue for the importance of measuring a particular sector or motivating a particular measurement concept.

Chapter 3 by Darrell Duffie offers a system for monitoring risks of systemically important financial firms that is simple, immediately implementable, and yet has enormous potential to identify vulnerabilities in the financial system. His 10-by-10-by-10 approach focuses on a core group of ten financial firms, measuring risk exposures for a specified set of ten scenarios, and measuring the ten largest counterparty exposures of each firm in this scenario. This approach is immediately implementable because many financial firms collect this sort of information regularly for enterprise risk management purposes. Thus, Duffie's approach builds on current practice and takes the second essential step of standardizing the risk management information across firms and eliciting information that can be compared and aggregated. Additionally, even though the focus is on a small group of financial firms, the fact that financial activity is concentrated among a few firms in most countries means that this monitoring system can shed light on the most important vulnerabilities in the financial system. Given the concentration of activity and the fact that core firms are often counterparties to noncore firms, the monitoring system may also shed light on activities of smaller financial firms. Furthermore, the proposal can easily be extended to a larger number of firms, scenarios, and counterparties.

Duffie outlines examples of the type of information that can be gleaned from the 10-by-10-by-10 system. If Treasury yields were to rise dramatically, how much would systemically important financial institutions gain or lose in total, from each other, and from others? From a macroprudential standpoint, the existence of a common large exposure to some risk factor suggests a potential vulnerability. The data can also reveal channels of contagion via a network. For example, if all firms have large counterparty exposure stemming from a given risk factor to a single firm, then that firm becomes a central node for contagion. In the recent crises, the 10-by-10-by-10 data may have pointed to the importance of AIG, even if AIG was not one of the ten financial firms on which data was collected.

Chapter 4 is by Juliane Beganau, Monika Piazzesi, and Martin Schneider and presents a way to remap the Federal Reserve's Flow of Funds to represent asset positions in terms of risk exposures along key risk factors. Modern finance views an asset as a random stream of payments. The market value of the asset today is the present value of the payment stream at the appropriate state prices. Clearly, only measuring and reporting the market value of an asset, as is the norm for trading assets in accounting statements, represents a small portion of the information about the asset. As an example, the market value of an interest rate swap derivative that is entered into today by a bank at a midmarket price is equal to zero. But of course the swap reflects significant nonzero exposure to changes in interest rates for the bank. Worse, reporting the book value of an asset, as is the norm for held-to-maturity assets in bank accounting, represents even less information about the asset. The focus on stocks of market value or book value assets may have been appropriate fifty years ago, but is not informative in a world of derivative securities, off-balance sheet vehicles, and other financial innovations.

The chapter offers a way to summarize payment stream information that is superior to asset market or book values. Assets are payment streams with exposures to a few underlying risk factors. For example, for fixed-income instruments including bonds and swaps, the literature on the term structure of interest rates shows that one can reduce the payment information of these assets into a few (e.g., three) underlying factors (e.g., level, slope, and curvature). This powerful observation implies that much of the fixed-income universe can be summarized as risk exposures to three factors. Moreover, the factor exposures of different assets can be linearly aggregated to summarize the overall exposure of a bank, a group of banks, a sector, or even an economy, to these risk factors. In essence, the chapter envisions remapping the Flow of Funds in terms of these exposures to risk factors. The authors argue that there is substantial information in currently reported data to take steps in this direction. Indeed, in a related paper (Beganau, Piazzesi, and Schneider 2012), the authors show how to use Bank Call Report data to infer interest rate factor exposures for a number of the largest banks in the United States.

Chapter 5 is by Robert L. McDonald and describes how information from margins that are provided by traders to derivatives (e.g., futures or swaps) clearinghouses can be used to estimate risk and liquidity risk exposures. The central idea in the chapter is that margin/collateral protects counterparties against credit losses and is thus an economic measure of exposure that differs by asset and by the topology of risk. Thus, for example, information on the aggregate amount of margin, say, on interest rate futures reflects the size of interest rate exposures transacted in the economy. McDonald makes a strong case that margin information that is currently collected can be valuably used to measure exposures, and also discusses how regulations under Dodd-Frank may be implemented to most effectively use margin information. The current version of Dodd-Frank fails to use this information, despite the fact that McDonald's ideas are among the most implementable of the measurement schemes outlined in this book.

Chapter 6, by Viral V. Acharya, is complementary to chapter 5. While McDonald focuses on derivatives that are cleared in exchanges, Acharya focuses on the derivatives that remain entirely over the counter. Currently most derivatives transactions fall into the latter category, and even with regulatory incentives to migrate derivatives clearing onto exchanges, it is likely that a significant share of derivatives trades will remain over the counter. Acharya offers an excellent overview of the ways in which financials currently disclose information on their derivative positions in public filings, noting the lack of a standard across firms and the shortcomings in currently reported information. He then discusses how to standardize reporting and what to report. In principle, there is a great deal of salient information ranging from derivative exposures by maturity, to exposures by counterparty, to contingent exposures (i.e., on a given stress). Like McDonald, he emphasizes the importance of margin call exposure, notably what he labels the "margin coverage ratio" (MCR) that compares a firm's cash position to its margin call exposure under stress scenarios.

Chapters 7 and 8 focus on response indicators. Systemic risk has an endogenous component that is driven by the response of economic actors. For example, if the financial sector is highly levered, then even a small decline in asset values can trigger fire-sales of assets, which further lower asset values. Likewise, if banks have little liquidity and a preponderance of short-term debt, then they risk bank runs.

Chapter 7 by Markus Brunnermeier, Arvind Krishnamurthy, and Gary Gorton discusses ways to measure liquidity. While the measurement of a quantity like bank capital is fairly clear, measuring the "liquidity" of a bank's balance sheet is far less straightforward. The chapter begins by discussing the theoretical literature on liquidity and explaining how to measure liquidity from the standpoint of these models. It then turns to practical challenges in liquidity measurement through a series of illustrative examples. Brunnermeier, Krishnamurthy, and Gorton then describe a liquidity mismatch index (LMI), motivated by theory, and reflecting the practical challenges in liquidity measurement. An important feature of the LMI is that it can be aggregated across firms. Thus the measure naturally describes liquidity mismatch at the firm, industry, and economy-wide levels. The chapter discusses the ways in which the LMI can be used to assess systemic risk. As a "response indicator" about market participants' reaction to an adverse shock, it is an important building block in the risk topography framework outlined in Brunnermeier, Gorton, and Krishnamurthy (2012).

Chapter 8, by John Geanakoplos and Lasse Heje Pedersen, discusses the measurement of leverage. The chapter begins by discussing the importance of leverage measurement as a response indicator, and as a factor in financial crises. An important observation made by Geanakoplos and Pedersen is that leverage on new loans and leverage on old (preexisting) loans are two conceptually different measures that are each informative. The authors point out that the leverage on new loans is a measure of current credit conditions. The average or old leverage instead signals the economy's past vulnerability to negative shocks. The authors point out that new leverage can be well captured by measuring margin requirements—haircuts on repo loans, or loan-to-value requirements on durable goods purchases. Indeed, coming from different points of view, Acharya, McDonald, as well as Geanakoplos and Pedersen describe the value of measuring margins at the asset level, underlining the value of such a measurement.

Chapters 9, 10, and 11 tackle financial intermediation and credit markets. While the textbook financial intermediary borrows short and lends long, in practice there is a great deal of texture in both the short and long of this intermediation. These chapters delve into this texture.

Chapter 9 focuses on the repo market and the security lending markets, which are key short-term funding markets for banks and have witnessed run-like behavior in the crisis (see Gorton and Metrick 2010; Krishnamurthy, Nagel, and Orlov 2012). Despite the importance of these markets, there is little data on the prices and quantities of trade in these markets. Tobias Adrian, Brian Begalle, Adam Copeland, and Antoine Martin provide a comprehensive overview of the structure of the repo markets, their function, the available data sources on repo and what is known about it, as well as what is not known. One of their observations is that repo is transacted primarily in two ways, via a triparty system and via a bilateral system. The available data from the crisis suggests that these systems behaved very differently, with far more stability of the haircuts in the triparty market compared to the bilateral market. Without data on these markets, it is hard to pinpoint what drove these differences. Yet, without such an understanding it is also hard to spot vulnerabilities in the short-term funding markets. This chapter describes the type of data that is needed in order to better understand these important short-term funding markets.

Chapters 10 and 11 consider the lending side of intermediaries. A key amplification mechanism identified by the theoretical literature is the possibility of a credit crunch whereby a disruption in the supply of new bank loans, through losses on existing loans, for example, reduces spending and production, exacerbating a downturn, and further increasing losses on existing bank loans. These chapters offer suggestions on how to measure a credit crunch that may be developing.

In chapter 10 William F. Bassett, Simon Gilchrist, Gretchen C. Weinbach, and Egon Zakrajšek point out the difficulties in analyzing new bank loans based on existing data. Most existing sources mix existing loans and new loans, measuring the total amount of loans at a given point in time, or failing to distinguish between loans made under existing commitments and new commitments. Their chapter offers an explicit and easily implementable suggestion to alter the data collected in Call Reports in a manner that can get at the key flows of new lending.

Chapter 11 by Atif Mian discusses the benefits of implementing a credit registry, which contains microlevel data detailing lending between every commercial borrower and bank. Such credit registry data are increasingly available in many countries, and have been used in studies by Mian in the case of Pakistan and Spain. As is well understood, a key difficulty in identifying a credit crunch is in disentangling whether a contraction in the volume of bank loans is due to loan supply factors or loan demand factors. Mian discusses in the context of his past work how a credit registry can help in identifying supply separate from demand. Although a credit registry is demanding in terms of data requirements, Mian points out the many ways in which such data can help identify credit supply shocks and further researchers' understanding of the link between financial intermediation and the macroeconomy.

Chapters 12, 13, and 14 address the household sector. Chapter 12 by Robert E. Hall lays out the case for the importance of measuring the household sector. As Hall argues, households have played a central role in recent events: they increased borrowing and leverage dramatically in the period from 2002 to 2006, and since then have suffered from house price collapses and "levered losses." As a consequence, households have cut back on expenditures, with detrimental effects on output and employment. Given that the majority of households are dependent on financial institutions for credit, measuring the household sector is essential to understanding connections between financing and macroeconomic activity.

What are the main aspects of the household sector that need to be measured? Chapter 13 by Jonathan A. Parker lays out a comprehensive approach to measuring the household sector, which he titles LEADS (liabilities, earnings, assets, demographics, and financial sophistication). Parker argues that detailed information is needed to measure liquid wealth (assets minus liabilities) as well as lifetime wealth (wealth plus future income and benefits) in order to understand the covariance of a given household's wealth with macroeconomic factors. With such information, one can characterize the exposure of groups of households to a macroeconomic factor such as real estate prices. This would allow regulators to better understand how a fall in real estate may affect household expenditure behavior. To get at the wealth variable, we need information on liabilities, earnings, assets, and demographics. Parker describes the current data available to construct wealth as well as other data that may be required. This discussion will be valuable to anyone involved in measurement of the household sector. Parker also makes a strong case to measure the financial sophistication of households. There are likely many unsophisticated households who may be subject to systematic errors in their financial planning. Such errors may compound the impact of a macroeconomic shock. Parker concludes, with the eye of a researcher, by describing how data should be made public to maximize its use in research.

Chapter 14 by Amir Sufi drills in on one particular risk stemming from the household sector. Sufi seeks data to determine when an increase in household leverage may pose a risk to the macroeconomy. He suggests that such a risk arises when the increase is driven by an expansion of credit supply. Drawing on his own work with Mian, he outlines data and a methodology that can be used to measure credit supply expansions. The data is in some regard similar to the credit registry data that Mian outlines in chapter 11 for firms, but applied to households. In particular, Sufi suggests microlevel panel data on household consumption and wealth. Much of this data exists currently but is not accessible to researchers. Thus, Sufi's chapter is a call for organizing existing data and making this data available.

Chapter 15 by V. V. Chari turns to nonfinancial firms. Many theoretical models highlight the impact of financial frictions on firms' investment decisions. That is, if many firms have high leverage and limited liquidity, then a downturn may force firms to cut back on investment, which can have macroeconomic consequences. Chari presents the available aggregate data on flows between nonfinancial firms and the rest of the economy and shows that such data does reveal evidence of financial frictions. Financial frictions are only present in subsets of the firms, and to understand these frictions one needs microlevel data. Chari discusses the available data sets and notes that the biggest need is for financial statements of privately held firms. Compustat data covers large public firms, but these are the firms least affected by financial frictions. While data on privately held firms exist within the IRS, they are not public. Chari suggests a manner by which the data can be publicized and made available to researchers.

Chapter 16 by Eugenio Cerutti, Stijn Claessens, and Patrick McGuire discusses cross-border issues. Prominent narratives of the recent financial crisis emphasize the global nature of banking. Imbalances in one region of the world can quickly propagate to others and exacerbate macroeconomic risks. Cerutti, Claessens, and McGuire argue that to understand global banking, we need data at the bank level covering operations across countries. As an example from the recent crisis, cross-currency funding played an important role and led to the establishment of central bank foreign-exchange swap lines. To study this type of issue, one needs data at the bank level on foreign-exchange swap use and foreign sources of funding. But such data does not exist currently. Bank-level data that are collected by supervisors are not widely shared, generally not even across supervisory jurisdictions, and only broad aggregates are publicly disclosed. While there has been some progress on filling these data gaps by the International Monetary Fund (IMF) and the Bank for International Settlements (BIS), there remain significant deficiencies. This chapter draws attention to these important issues and calls for further progress to close these international data gaps.

To conclude this introduction, we return to the analogy of national income accounting. The development of national income accounts has been critical for much of our knowledge of the way economies function. The financial crisis has shown that our understanding of the function of finance in the macroeconomy is still very incomplete. In addition to measuring only stock and flow variables, the recent financial crisis has shown the importance of risk measurement.

In this book we aim to assemble many important building blocks—or at least the conceptual cornerstones—for a modern risk measurement system. Of course, one may ask whether we have missed important components and failed to identify knowledge gaps. One gap that we are aware of concerns expectations. It is important to get some indication that market participants are driven by collective misjudgments and distorted expectations. We tried but failed to commission a chapter that proposes new survey methods to elicit market participants' expectations and tail risk perceptions. The chapters in this book are particularly focused on vulnerabilities that can lead to an amplified response to negative shocks. As a large part of the risk is endogenous and self-generated by the system, the measurement can only be understood in connection with general equilibrium models. Additional data will allow researchers and regulators to discriminate across models and is thus essential to improve our understanding of macrofinancial links. We hope that the chapters in this book will aid in academic and regulatory efforts to address these issues.

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