TECHNOLOGICAL CHANGE, FINANCIAL INNOVATION, AND DIFFUSION IN BANKING

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ABSTRACT

This paper discusses the technological change and financial innovation that has been experienced by commercial banking over the past 25 years. The paper first describes the role of the financial system in economies and how technological change and financial innovation can improve social welfare. We then survey the literature relating to several specific financial innovations -- delineated as new products or services, new production processes, or new organizational forms. We find that the past quarter century has been a period of substantial change in terms of banking products, services, and production technologies. Moreover, while much effort has been devoted to understanding the characteristics of users and adopters of financial innovations and the attendant welfare implications, we still know little about how and why financial innovations are initially developed.

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1. INTRODUCTION

The commercial banking business has changed dramatically over the past 25 years, due in large part to technological change.[1] Advances in telecommunications, information technology, and financial theory and practice have jointly transformed many of the relationship-focused intermediaries of yesteryear into data-intensive risk management operations of today. Consistent with this, we now find many commercial banks embedded as part of global financial institutions that engage in a wide variety of financial activities.

To be more specific, technological changes relating to telecommunications and data processing have spurred financial innovations that have altered bank products and services and production processes. For example, the ability to use applied statistics cost-effectively (via software and computing power) has markedly altered the process of financial intermediation. Retail loan applications are now routinely evaluated using credit scoring tools, rather than using human judgment. Such an approach makes underwriting much more transparent to third parties and hence facilitates secondary markets for retail credits (e.g., mortgages and credit card receivables) via securitization.[2] Statistically based risk measurement tools are also used to measure and manage other types of credit risks – as well as interest rate risks – on an ongoing basis across entire portfolios. Indeed, tools like value-at-risk are even used to determine the appropriate allocation of risk-based capital for actively managed (trading) portfolios.

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[1] Restrictions on commercial banks' ability to diversify geographically and across product space were also significantly relaxed during this time, especially in the United States. This trend has significantly reinforced technological change in terms of driving the observed evolution of commercial banking over the past 25 years.

[2] There is also a secondary market for "wholesale" loans to large corporations, via a loan syndication process. This market has also benefited from securitization through the market for "collateralized loan obligations," or CLOs, which are a type of "collateralized debt obligation," or CDO. CDOs are discussed further below.

This chapter will describe how technological change has spurred financial innovations that have driven the aforementioned changes in commercial banking over the past 25 years. In this respect, our survey is similar to that of Berger (2003).[3] However, our analysis distinguishes itself by reviewing the literature on a larger number of new banking technologies and synthesizing these studies in the context of the broader economics literature on innovation. In this way, the chapter is more like our own previous survey of empirical studies of financial innovation (Frame and White, 2004). We note that this survey is U.S.-centric, owing to our own experiences, the fact that many financial innovations originate in the U.S., and that most studies of such innovations rely on U.S. data. Before proceeding, it will be helpful to understand better what is meant by financial innovation.

2. BACKGROUND: THE ROLE OF FINANCE AND FINANCIAL INNOVATION

As noted by Merton (1992, p. 12), the primary function of a financial system is to facilitate the allocation and deployment of economic resources, both spatially and across time, in an uncertain environment. This function encompasses a payments system with a medium of exchange; the transfer of resources from savers to borrowers; the gathering of savings for pure time transformation (i.e., consumption smoothing); and the reduction of risk through insurance and diversification.

The operation of a financial system involves real resource costs (labor, materials, and capital) employed by financial intermediaries (e.g., commercial banks) and by financial facilitators

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[3] See also Berger, Kashyap, and Scalise (1995) for discussion of the role of technological and regulatory changes in transforming the U.S. banking industry.

(e.g., mortgage brokers). Much of these resources are expended in the data collection and analyses in which financial market participants engage so as to deal with problems of asymmetric information. There are also uncertainties about future states of the world that generate risks, which for risk-averse individuals represent costs. In this environment, new financial products and services that can better satisfy financial system participants' demands should generally be welcomed by those participants.

Hence, we define a financial innovation as something new that reduces costs, reduces risks, or provides an improved product/service/instrument that better satisfies financial system participants' demands. Financial innovations can be grouped as new products (e.g., subprime mortgages) or services (e.g., Internet banking); new production processes (e.g., credit scoring); or new organizational forms (e.g., Internet-only banks).[4]

The centrality of finance in an economy and its importance for economic growth (e.g., Levine 1997) naturally raises the importance of financial innovation – and its diffusion. Since finance is a facilitator of virtually all production activity and much consumption activity, improvements in the financial sector will have direct positive ramifications throughout an economy. Further, since better finance can encourage more saving and investment and can also encourage better (more productive) investment decisions, these indirect positive effects from financial innovation add further to its value for an economy. The importance of financial innovation has been discussed in a number of articles, most notably: Van Horne (1985), Miller (1986, 1992), Merton (1992, 1995), and Tufano (2003).

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[4] Of course, if a new intermediate product or service is created and used by banks, it may then become part of a new financial production process.

Given its importance, an understanding of the conditions that encourage innovation would appear to be worthwhile. After all, observed streams of innovations are clearly not uniform across all enterprises, across all industries, or across all time periods. The general innovation literature in economics has sought to uncover the environmental conditions that affect the stream of innovations – focusing on hypotheses concerning roughly five structural conditions: (1) the market power of enterprises; (2) the size of enterprises; (3) technological opportunity; (4) appropriability; and (5) product market demand conditions.[5] Of course, when environmental changes occur, we expect to observe an initial wave of financial innovations followed by a new equilibrium flow consistent with the new environmental conditions. Over the past 25 years, each of these environmental conditions (1)-(5) was markedly altered – resulting in substantial changes to the commercial banking industry.

Furthermore, as we noted in our earlier review article (Frame and White 2004), there has been a surprising dearth of empirical studies that test hypotheses with respect to financial innovation in general. This is especially true for hypotheses that focus on the structural conditions that encourage innovation.[6] Instead, the comparatively few empirical studies that have been done tend to focus on the characteristics of users/adopters of innovations – sometimes on a cross-sectional basis and other times in the context of the diffusion of the innovation. In surveying the literature in preparation for this chapter, we find that more empirical studies have appeared, but the field is still

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[5] See Cohen and Levin (1989) and Cohen (1995) for comprehensive surveys of this literature. The first two hypotheses are associated with Schumpeter (1950).

[6] We previously identified only two papers that tested hypotheses concerning structural conditions that encourage financial innovation (Ben-Horim and Silber 1977 and Lerner 2002). Lerner (2006) has made a more recent contribution.

relatively sparse, and the studies still focus largely on the characteristics of users/adopters. This finding represents a supplementary contribution of this chapter.

3. FINANCIAL INNOVATION AND BANKING: 1980-2005

In this section, we survey the literatures pertaining to several specific financial innovations appearing over the past 25 years or so that were specifically driven by technological change. We have organized our discussion along the lines of the three major categories that we described in Section 2: new products and services; new production processes; and new organizational forms.

A1. Products

Mortgage loans are one suite of products that have experienced a great deal of change over the past 25 years in the United States. In 1980, long-term fully amortizing fixed-rate mortgages were the norm; and this product was offered primarily by thrift institutions. Moreover, these loans required substantial downpayments and a good credit history; and the accumulated equity was relatively illiquid.

These characteristics have markedly evolved. The first big change occurred in the early 1980s with the widespread introduction of various types of adjustable-rate mortgages (ARMs), which had previously been banned by federal regulators.[7] The Tax Reform Act of 1986, which ended federal income tax deductions for non-mortgage consumer debt, spurred substantial growth in home equity lending.[8] One mortgage innovation more directly tied to technological change is

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[7] See Strunk and Case (1988, ch. 5) and White (1991, p. 65) for further discussion.

[8] Manchester and Poterba (1989) report that second mortgages accounted for 3.6% of residential mortgage debt outstanding at the beginning of the 1980s and quickly rose to 10.8% by the end of 1987.

subprime lending, which was originally predicated on the use of statistics for better risk measurement and risk-based pricing to compensate for these higher risks. However, the subprime mortgage crisis has uncovered significant shortcomings in the underlying statistical models.

Subprime Mortgages. Subprime mortgage lending, broadly defined, relates to borrowers with poor credit histories (e.g., a FICO score below 620) and/or high leverage as measured by either debt/income (personal leverage) or loan-to-value (property leverage). This market grew rapidly in the U.S. during the first decade of the twenty-first century – averaging about 20% of residential mortgage originations between 2004 and 2006. At the end of 2007, subprime mortgages outstanding stood at $940 billion; down from over $1.2 trillion outstanding the previous year (Inside Mortgage Finance 2008).

Subprime mortgage lending acts to expand the pool of potential homeowners and helped to lead the U.S. to a record homeownership rate in 2004 of 69.2% -- even in the face of declining housing affordability in many areas of the country. On the other hand, subprime mortgages typically come with more onerous terms, like higher interest rates and prepayment penalties. Hence there is some concern that subprime lending can be "predatory" in nature, especially since lower-income and/or minority households are much more likely to have subprime mortgages. The wave of U.S. subprime mortgage defaults (and associated foreclosures) during 2007 and 2008 has led to a very public discussion about the social benefits and costs of subprime lending and about the manner in which such loans are marketed and financed.

The significant spillover effects of the subprime mortgage crisis on global credit markets has also led to serious questions about the financial markets' dependence on applied statistics (including the choice of historical time frame for calibration) as the basis of risk measurement and management

as well as the construction of increasingly complex structured finance products. As discussed below, these represent important examples of process financial innovations for commercial banks in recent years.

Prior to the crisis, some research sought to explain the existence and efficiency of the subprime mortgage market. Lax, Manti, Raca, and Zorn (2004) characterize subprime borrowers – finding that (relative to prime borrowers) they are more likely to have poor credit, lower-incomes, less education, and belong to minority groups. Chomsisengphet and Pennington-Cross (2006) provide several stylized facts about subprime mortgage loans over time – specifically borrower credit quality, interest rates, downpayment requirements, and the presence of prepayment penalties. Crews-Cutts and Van Order (2005) explain various stylized facts pertaining to subprime loan pricing and performance in the context of financial contracting theory. Chinloy and Macdonald (2005) discuss how the subprime market helps to complete the credit supply schedule and therefore enhance social welfare, while Nichols, Pennington-Cross, and Yezer (2005) explain why prime and subprime mortgage markets are distinct and not continuous. Other papers look at the geographic distribution of subprime borrowers generally (Calem, Gillen, and Wachter 2004) and the incidence of prepayment penalties particularly (Farris and Richardson 2004). Finally, there are a number of papers that study how local predatory lending laws affect subprime mortgage credit supply – e.g., Elliehausen and Staten (2004); Harvey and Nigro (2003, 2004); Quercia, Stegman, and Davis (2004); and Ho and Pennington-Cross (2006a).

Another strand of research studied subprime loan termination by jointly estimating empirical models of prepayment and default (e.g., Alexander, Grimshaw, McQueen, and Slade 2002; Pennington-Cross 2003; Danis and Pennington-Cross 2005a; Ho and Pennington-Cross 2006b,

2006c; and Pennington-Cross and Chomsisengphet 2007). Related papers have sought to explain the length of time between delinquency and default (Danis and Pennington-Cross 2005b); time in foreclosure (Pennington-Cross 2006; Capozza and Thomson 2006); and loss given default (Capozza and Thomson 2005).

Since the onset of the subprime mortgage crisis, research has attempted to identify various sources of the problem. Mayer, Pence, and Sherlund (forthcoming) provide an overview of the attributes of subprime mortgages outstanding during this time and investigate why delinquencies and defaults increased so substantially.[9] These authors, as well as Gerardi, Lehnert, Sherlund, and Willen (forthcoming), point to a significant increase in borrower leverage during the mid-2000s, as measured by combined loan-to-value (CLTV) ratios, which was soon followed by falling house prices.

CLTV is important because economic theory predicts that borrowers with positive home equity will not default. That is, distressed borrowers with positive equity could borrow against this equity or simply sell the home and pocket any net proceeds. Hence, negative equity (owing more than the home is worth) is a *necessary condition* for mortgage default. (See Foote, Gerardi, and Willen, 2008 for an overview of this issue.) As U.S. house prices declined in many parts of the U.S. during 2007 and 2008, an increasing number of homeowners found themselves with negative equity in their homes. Many borrowers facing negative income shocks – especially financially fragile subprime mortgage borrowers – subsequently defaulted on their loans.

But how did such financially fragile borrowers obtain mortgage financing in the first place?

[9] In related work, Mayer and Pence (2008) examine the geographic dispersion of subprime lending (states/cities/neighborhoods) for 2005.

Some research attention has been paid to the evolution of subprime mortgage underwriting standards. In particular, the focus has been on declining underwriting standards as measured by observable characteristics (e.g., Mayer, Pence, and Sherlund, forthcoming) or by increased forecast errors from empirical default models (Demyanyk and Van Hemert 2008; Rajan, Seru, and Vig 2008).[10] Keys, Mukherjee, Seru, and Vig (2008) find that such unobserved negative characteristics are correlated with the use of securitization and attribute this to lax screening by subprime mortgage originators. The declining underwriting standards likely emanated from the sizeable rise in U.S. house prices between 2001 and 2006, which likely masked much of the weakness.

A2. Services

Recent service innovations primarily relate to enhanced account access and new methods of payment – each of which better meets consumer demands for convenience and ease. Automated teller machines (ATMs), which were introduced in the early 1970s and diffused rapidly through the 1980s, significantly enhanced retail bank account access and value by providing customers with around-the-clock access to funds. ATM cards were then largely replaced through the 1980s and 1990s by debit cards, which bundle ATM access with the ability to make payment from a bank account at the point-of-sale. Over the past decade, remote access has migrated from the telephone to the personal computer. Online banking, which allows customers to monitor accounts and originate payments using "electronic bill payment," is now widely used. Stored-value, or prepaid, cards have also become ubiquitous.[11]

[10] Relatedly, Dell'Ariccia, Igan, and Laeven (2008) document a decline in the denial rate on subprime mortgage applications and find that this decline is correlated with geographic areas with higher house price appreciation and securitization rates.

[11] Other small-dollar payment options have emerged in recent years, like smart cards and PayPal. However, we do not discuss these further due to their limited penetration and a dearth of research relating to "electronic cash."

Debit Cards. Debit cards are essentially "pay-now" instruments linked to a checking account whereby transactions can happen either instantaneously using online (PIN-based) methods or in the near future with offline (signature based) methods. Consumers typically have the choice of using online or offline methods, and their selection often hinges on the respective benefits: Online debit allows the cardholder also to withdraw cash at the point-of-sale, and offline provides float. According to ATM & Debit News (2007), there were approximately 26.5 billion debit transactions in the U.S. during 2006. This is up from 6.5 billion transactions in 1999 – a four-fold increase.[12]

Much of the research pertaining to debit cards relates to identifying the most likely users of this payment instrument. Such demand-side explorations have been conducted individually as well as jointly across multiple payment options. Stavins (2001), for example, uses data from the 1998 Survey of Consumer Finances (SCF) and finds that debit usage is positively related to educational attainment, homeownership status, marital status, business ownership, and being a white collar worker; and is negatively related to age and net worth. Klee (2006) extends this analysis to consider the 1995, 1998, and 2001 SCFs and reports a secular increase in adoption driven by similar demographic factors.[13] Additional U.S. evidence is provided by Mantel and McHugh (2001) using survey data from Vantis International; Hayashi and Klee (2003) using data from a 2001 survey conducted by Dove Consulting; as well as Borzekowski and Kiser (2008) and Borzekowski, Kiser,

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[12] It is worth noting, however, that debit cards were originally introduced as an innovation in the early 1980s but did not succeed at that time. Among the problems may have been the following: The likely potential adopters (younger, more educated, more affluent households) usually also had credit cards and would have been sensitive to the value of the float on a credit card at a time of relatively high interest rates. The quick payment attribute of a debit card was therefore not a "value proposition" for this group.

[13] See also Anguelov, Hilgert, and Hogarth (2004) for the relevant statistics pertaining to these surveys. Also, using data across four SCFs, Zinman (2009) reports that, other things being equal, the choice of using debit cards is positively related to being a "revolver" of credit card balances (as opposed to paying off such balances each month).

and Ahmed (2006) using 2004 data from the Michigan Surveys of Consumers.[14]

Some additional analysis by Hayashi and Klee (2003) studied the circumstances under which consumers are likely to use debit cards and found that these are more often used at grocery stores and gas stations than at restaurants. Related to this, the authors also find that debit card usage is positively related to the incidence of self-service transactions.

Online Banking. As households and firms rapidly adopted Internet access during the late-1990s, commercial banks established an online presence. According to DeYoung (2005), the first bank websites were launched in 1995; and by 2002 nearly one-half of all U.S. banks and thrifts operated transactional websites. As of 2007, bank call report data suggests that 77.0 percent of commercial banks offer transactional websites (and these banks control 96.8 percent of commercial bank deposits).

The primary line of research relating to online banking has been aimed at understanding the determinants of bank adoption and how the technology has affected bank performance.[15] In terms of online adoption, Furst, Lang, and Nolle (2002) find that U.S. national banks (by the end of the third quarter of 1999) were more likely to offer transactional websites if they were: larger, younger, affiliated with a holding company, located in an urban area, and had higher fixed expenses and non-interest income.[16] Turning to online bank performance, DeYoung, Lang, and Nolle (2007)

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[14] International evidence is provided by Jonker (2005) for the Netherlands and by Loix, Pepermans, and Van Hove (2005) for Belgium.

[15] See also Pennathur (2001) for a discussion of the various risks associated with online banking.

[16] Sullivan (2000) presents some statistics for banks in the 10th Federal Reserve District that are generally consistent with this study.

report that Internet adoption improved U.S. community bank profitability – primarily through deposit-related charges. In a related study, Hernando and Nieto (2007) find that, over time, online banking was associated with lower costs and higher profitability for a sample of Spanish banks. Both papers conclude that the Internet channel is a complement to – rather than a substitute for – physical bank branches.[17]

Unlike the aforementioned studies, Mantel (2000) focuses on the demand-side of electronic/online bill payment – empirically analyzing the demographic characteristics of users. Among other things, the author finds that electronic bill payers tend to be: older, female, higher income, and homeowners.

Prepaid Cards. As the name implies, prepaid cards are instruments whereby cardholders "pay early" and set aside funds in advance for future purchases of goods and services. (By contrast, debit cards are "pay-now", and credit cards are "pay later".) The monetary value of the prepaid card resides either on the card or at a remote database. According to Mercator Advisory Group, prepaid cards accounted for over $180 billion in transaction volume in 2006.

Prepaid cards can be generally delineated as either "closed" systems (e.g., a retailer-specific gift card, like Macy's or Best Buy) or "open" systems (e.g., a payment-network branded card, like Visa or MasterCard). Closed-system prepaid cards have been effective as a cash substitute on university campuses, as well as for mass transit systems and retailers. Open-card systems, while less effective in this regard to date, may ultimately have greater promise owing to functionality that more resembles traditional debit and credit cards. For example, these prepaid cards can be used to

[17] Additional evidence is offered by Ciciretti, Hasan, and Zazzara (2009), who also find that Italian banks offering Internet-related services had higher profitability (and stock returns) relative to their peers.

withdraw money from an ATM and to make purchases or pay bills in person, over the phone, or online. Cheney and Rhine (2006) discuss two types of open-system prepaid programs – payroll cards and general spending reloadable cards – each of which provides functions similar to deposit accounts. Payroll cards, which were first introduced in 2001, are particularly attractive for unbanked workers and their employers because of lower transactions costs (McGrath 2005). Such cards have also been used to deliver welfare benefits and disaster relief. Reloadable cards, which are typically offered through grocery stores and convenience stores, have most often been targeted to immigrants for remittances, to travelers, or to parents for teen purchases.

Some descriptive research relating to prepaid cards exists and is focused on certain public policy issues related to this payments medium. Furletti and Smith (2005) note the lack of state and federal consumer protections, but mention that card associations and bank-issuers have voluntarily extended some safeguards in practice, like "zero liability" and "charge-back" provisions. Sienkiewicz (2007) discusses the potential for prepaid cards to be used in money laundering schemes. The author notes instances with offshore card issuance and the ability to access cash at ATMs as being the most vulnerable to illicit activity.

B. Production Processes

The past 25 years have witnessed important changes in banks' production processes. The use of electronic transmission of bank-to-bank retail payments, which had modest beginnings in the 1970s, has exploded owing to greater retail acceptance, online banking, and check conversion. In terms of intermediation, there has been a steady movement toward a reliance on statistical models. For example, credit scoring has been increasingly used to substitute for manual underwriting – and has been extended even into relationship-oriented products like small business loans. Similar credit

risk measurement models are also used when creating structured financial products through "securitization". Statistical modeling has also become central in the overall risk management processes at banks through portfolio stress testing and value-at-risk models – each of which is geared primarily to evaluating portfolio value in the face of significant changes in financial asset returns.

Automated Clearinghouse (ACH). An automated clearinghouse (ACH) is an electronic funds transfer network connecting banks – primarily used for recurring, small-dollar payments. While several ACH networks emerged in the 1970s, volumes grew only modestly through the 1980s, being used almost exclusively for direct payroll deposits. Over the past 15 years, however, consolidation has occurred and volumes have soared. According to the National Automated Clearing House Association, the number of ACH payments has increased from just under 2 billion in 1991 to 16 billion in 2006. (Over the same timeframe, the dollar value of ACH items transmitted rose from $6.9 trillion to $33.7 trillion.) These payments, in turn, are now made through only two ACH networks: The New York Clearinghouse's Electronic Payments Network and the Federal Reserve System's FedACH.

The modest literature on ACH networks has been aimed at understanding supply and demand conditions in support of FedACH pricing policies. Bauer and Hancock (1995) found that over the 1979-1994 period the cost of processing an ACH item fell dramatically owing to scale economies, technological change, and lower input prices.[18] Stavins and Bauer (1999), on the other hand, estimated ACH demand elasticities by exploiting FedACH price changes over time – finding ACH demand to be highly inelastic. The two most recent papers studied network externalities for

[18] Using a much smaller sample, Bauer and Ferrier (1996) also found support for the existence of ACH scale economies as well as significant allocative inefficiencies.

ACH. Gowrisankaran and Stavins (2004) find support for significant network externalities, which they ascribe to technological advancement, peer-group effects, economies of scale, and market power. Ackerberg and Gowrisankaran (2006) identify large fixed costs of bank adoption as the barrier to greater use of ACH transactions and thus to society's capturing the accompanying potential cost savings.

Small Business Credit Scoring. Banks use a number of different lending technologies to lend to informationally opaque small businesses (see Berger and Udell 2006 for a summary of these technologies). One new technology that was introduced in the 1990s and continues to evolve is small business credit scoring (SBCS). This technology involves analyzing consumer data about the owner of the firm and combining it with relatively limited data about the firm itself using statistical methods to predict future credit performance. Credit scores had long been pervasive in consumer credit markets (e.g., mortgages, credit cards, and automobile credits) – and resulted in widely available, low-cost, commoditized credits that are often packaged and sold into secondary markets.

The empirical literature studying SBCS has focused on the determinants of bank adoption and diffusion of this technology, as well as on how SBCS has affected credit availability. Two studies have statistically examined the determinants of the probability and timing of large banks' adoption of SBCS. Frame, Srinivasan, and Woosley (2001) and Akhavein, Frame, and White (2005) both find an important role for organizational structure in the adoption decision: banking organizations with fewer bank charters and more bank branches were more likely to adopt and also to adopt sooner. This suggests that large banks with a more "centralized" structure were more likely to adopt SBCS. The use of the SBCS technology still appears to be mostly limited to

large banking organizations. However, one recent study suggests that small banks now often make use of the consumer credit score of the principal owner of the firm (Berger, Cowan, and Frame 2007).

Several studies have focused on the relationship between SBCS adoption and credit availability. Three studies documented increases in the quantity of lending (Frame, Srinivasan, and Woosley 2001; Frame, Padhi, and Woosley 2004; Berger, Frame, and Miller 2005). One found evidence consistent with more lending to relatively opaque, risky borrowers (Berger, Frame, and Miller 2005); another with increased lending within low-income as well as high-income areas (Frame, Padhi, and Woosley 2004); and another with lending over greater distances (DeYoung, Glennon, and Nigro, 2008).[19]

Asset Securitization. Asset securitization refers to the process by which nontraded assets are transformed into tradable "asset-backed securities" (ABS) by repackaging cashflows.[20] Today, in the U.S., securitization is widely used by large originators of retail credit – specifically mortgages, credit cards, and automobile loans. As of year-end 2007, federally sponsored mortgage pools and privately arranged ABS issues (including private-label mortgage-backed securities) totaled almost $9.0 trillion of the $49.9 trillion in U.S. credit market debt outstanding. By contrast, as of year-end 1990, these figures were $1.3 trillion and $13.8 trillion,

[19] In cases in which SBCS is used in conjunction with other lending technologies, it is also shown to result in increased loan maturity (Berger, Espinosa-Vega, Frame, and Miller 2005) and reduced collateral requirements (Berger, Espinosa-Vega, Frame, and Miller 2006).

[20] The Government National Mortgage Association ("Ginnie Mae") was the first issuer of any kind of ABS – residential mortgage-backed securities (RMBS) – in 1970. The Federal Home Loan Mortgage Corporation ("Freddie Mac") was a "fast second", with its RMBS appearing in 1971.

respectively.[21]

A large number of books and articles have been devoted to the process of securitization and the analytics required to structure and value the resulting assets. As a result, we provide only a cursory review of the issues. Generally speaking, asset securitization involves several steps. The first is the sale of a pool of financial assets to a legally separate ("bankruptcy remote") trust against which liabilities (the ABS) are issued.[22] In this way, the original holder of the assets receives a cash payment, thereby liquefying its position. However, since the seller presumably has better information about the assets than does the buyer of the ABS (who thus faces the potential for "adverse selection"), the buyer requires some form of "credit enhancement" in the form of third-party guarantees, overcollateralization, or the creation of a priority of claims via "tranching".[23] While the first two forms of credit enhancement are straightforward, the last one requires some explanation.

Tranching involves the creation of two or more security types defined by their priority of claims.[24] The original seller often retains the most junior ("equity") security -- the one with the

[21] Thomas (2001, Table 1) documents the tremendous growth of securitization by presenting the number and dollar value of privately arranged ABS transactions between 1983 and 1997 as reported in the Securities Data Company's New Issues Data Base.

[22] This discussion implicitly assumes a "liquidating pool" of assets with fixed (but prepayable) terms to maturity. Some assets, like credit cards, are placed into "revolving pools," which allow for the ex post addition of assets, since these loans have no fixed payment amount or term.

[23] Investors may also believe that deal sponsors are additionally providing some level of implicit recourse as a method to maintain their reputation in the market. Higgins and Mason (2004) and Gorton and Souleles (2005) provide empirical evidence consistent with this conjecture – higher-rated sponsors execute ABS deals at tighter spreads. See also Cantor and Hu (2006) for an analysis of differences between bank-sponsored and other ABS deals.

[24] The case of two securities (senior and junior) is generally sufficient to make the stylized points about securitization, but in practice much more granular structures are observed.

lowest payment priority (and thus the first absorption of losses) – as a way of assuaging skeptical investors about the quality of the assets in the pool.[25] However, sophisticated investors -- such as hedge funds – sometimes also hold such positions.[26]

Besides liquidity, securitization may be socially beneficial insofar as it allows for lower-cost financing of loans (through the separation of origination and funding); securitization may also hold private benefits for depository institutions seeking to manage their required capital positions. Thomas (2001) presents empirical evidence that the stockholders of certain ABS issuers benefit from securitization – i.e., first-time issuers, large issuers, frequent issuers, lower-quality issuers, and bank-issuers.[27]

One recent innovation in the structured finance/securitization area is the introduction of collateralized debt obligations (CDOs). According to Longstaff and Rajan (2006) these instruments, which were first introduced in the mid-1990s, are now in excess of $1.5 trillion. Like ABS, CDOs are also liabilities issued by financial-institution-sponsored trusts, which essentially pool and restructure the priority of cash flows associated with other types of risky financial assets, including senior and mezzanine ABS, high-yield corporate bonds, and bank loans.[28] Lucas, Goodman, and

[25] This is consistent with important theoretical work in financial economics by Leland and Pyle (1977) and Myers and Majluf (1984) relating to capital structure more generally. See DeMarzo and Duffie (1999) and DeMarzo (2005) for similar discussion specific to asset-backed securities.

[26] Boot and Thakor (1993) and Plantin (2004) provide theoretical explanations for the sale of tranched securities to investors of differing financial sophistication.

[27] Prior empirical work by Lockwood, Rutherford, and Herrera (1996) and Thomas (1999) had previously found conflicting evidence using subsamples of the data. The former paper focused on 1985 to 1992 and the latter paper on 1991 to 1996.

[28] There are also "synthetic CDOs," in which the CDO entity does not actually own the pool of assets but instead owns a credit default swap. In this way, the sponsoring institution transfers the economic risk but not the legal ownership of the underlying assets. See Goodman (2002) and Gibson (2004) for overviews and discussions of the motivation for and risks

Fabozzi (2006, 2007) provide in-depth discussions of CDO purposes, structures, and risks. Most of the emerging literature relating to CDOs is aimed at risk measurement and pricing.[29] However, other work explores the relationship between CDOs and systemic risk (Krahnen and Wilde, 2006) and the relationship between banks' use of CDOs and their lending behavior (Goderis, Marsh, Castello, and Wagner 2007).

The precipitous rise in subprime mortgage defaults – and expectations of future defaults -- led to a significant decline in the value of subprime mortgage-backed securities and CDOs backed by such securities. This development, in turn, resulted in the freezing-up of secondary markets for subprime mortgages and mortgage securities. Subprime mortgages caught in the originate-to-distribute pipeline at that time were then returned to the originator's balance sheet. The material decline in asset values had serious consequences for leveraged investors with material exposures to subprime mortgage credit. This is how the subprime mortgage crisis evolved into a global financial crisis.

Some analysts have pointed to incentive conflicts inherent in the originate-to-distribute model of financial intermediation as a key reason for the magnification of the crisis -- that is, how and why the surge in defaults by subprime mortgage borrowers, who are inherently more risky borrowers, had such a negative effect on the value of investment-grade subprime mortgage-backed securities. Ashcraft and Schuermann (2008) identify seven key informational frictions that arise in the originate-to-distribute model; discuss how market participants work to minimize such frictions;

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inherent in these structures.

[29] See, for example, Duffie and Garleanu (2001), Hull and White (2004); Meneguzzo and Vecciato (2004); Yang, Hurd, and Zhang (2006); Longstaff and Rajan (2006); Kaniovski and Pflug (2007); and Glasserman and Suchintabandid (2007).

and speculate as to how this process broke down. The paper also provides an overview on how subprime mortgage securitization deals are structured and rated using detailed information from a securitized mortgage pool.

Risk Management. Advances in information technology (both hardware and software) and financial theory spurred a revolution in bank risk management over the past two decades. Two popular approaches to measuring and managing financial risks are stress-testing and value-at-risk (VaR). In either case, the idea is to identify the level of capital required for the bank to remain solvent in the face of unlikely adverse environments.

Stress testing involves constructing adverse scenarios for credit and/or interest rate conditions and then evaluating assets and liabilities – and thus solvency – under these stressed circumstances.[30] Fender and Gibson (2001) present a survey of stress-testing in financial institutions. Berkowitz (1999-2000) and Kupiec (2000) both discuss certain shortcomings of stress testing for risk management, including whether the results of such tests will generally achieve equity capital allocations sufficient to stave-off default under duress.

VaR relies on a probabilistic approach that evaluates the return distributions of assets. In this case, a bank would define a probability level of the return distribution (e.g., 99.9%) as an outer limit of exposure and then calculate the economic losses associated with that point on the distribution. Because of the focus on return distributions, VaR has been applied most widely to trading books, which are populated by readily marketable securities. Nevertheless, the principles involved have

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[30] Related stress testing procedures are also used by some central banks as a method of evaluating financial system resiliency in the face of shocks. See, for example, Cihak (2007), Goodhart (2006), Elsinger, Lehar, and Summer (2006), and Majnoni, Martinez-Peria, Blaschke, and Jones (2001).

also been applied to credit portfolios. A large number of books and articles have been devoted to VaR – primarily centered on the appropriate characterization of return distributions for various assets and the use of VaR principles in the Basel II Capital Accord.

C. Organizational Forms

New bank organizational forms have emerged in the United States over the past few decades. Securities affiliates (so-called "Section 20" subsidiaries or the creation of "financial holding companies") for very large banks and Subchapter S status for very small banks, were the byproduct of regulatory/legal evolution. Indeed, only one new organizational form, the Internet-only bank, arose from technological change. These institutions, which quickly emerged and disappeared, may represent an interesting laboratory for the study of "failed" financial innovations. We believe that understanding such experimental failures may hold important insights for understanding the keys to successful financial innovations.

The dramatic increase in individuals' use of the Internet in the 1990s created the possibility of a new organizational form in banking: the Internet-only bank. According to Delgado, Hernando, and Nieto (2007), as of mid-year 2002, there were some 35 Internet-only banks operating in Europe and another 20 in the U.S. However, in Europe, virtually all of these banks were affiliated with existing institutions, while in the U.S. they tended to be de novo operations. This may explain why most/all of the U.S. Internet-only banks have disappeared (through acquisition, liquidation, or closure) or established a physical presence to supplement their Internet base. This suggests that the dominant technology is one of "clicks and mortar."

DeYoung (2001, 2005) finds that, as compared with conventional de novo banks, the Internet de novo banks are less profitable due to low business volumes (fewer deposits and lower

non-interest income) and high labor expenditures. However, the author also reports that the financial performance gaps narrow quickly over time due to scale effects. Delgado, Hernando, and Nieto (2007) similarly find that European Internet banks demonstrate technology-based scale economies.

4. CONCLUSIONS

This chapter has reviewed the literature on technological change and financial innovation in banking since 1980. This quarter century has been a period of substantial change in terms of bank services and production technologies, but much less so with respect to organizational form. As this survey indicates, although much has been learned about the characteristics of users and adopters of financial innovations and the attendant welfare implications, we still know little about how and why financial innovations are initially developed. This remains an important area for further research.

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