“Liquidity and Macroeconomics: a vision and my research agenda”

by Saki Bigio

I am a macroeconomic theorist that builds quantitative models. I concentrate my research on the intersection of business cycle analysis, money and banking, and corporate finance. My agenda aims to understand how financial architectures and their imperfections impact macroeconomic performance. I have the utilitarian objective of providing insights as to how policy can exploit those imperfections to improve outcomes. The following lines review this agenda.

This research statement is somewhat unconventional because I will talk not only talk about the content of papers, but also about the context that motivated these papers at a given time. Developing a research agenda is an act of exploration: as scientists, we are always looking for something, and while intuition guides us, we do not know what we will find. I think others, especially students, will value hearing about how papers were conceived and not only about their content. For that reason, I structure the statement tracing connections between the policy issues, what I saw as a void in the literature, and the technical connection between papers.

How did I kick-start my agenda? The agenda I have carried out as an assistant professor began when I was finishing my PhD coursework at NYU, in the midst of the 2008-2009 financial crisis. Most macroeconomists will acknowledge that, at the time, business cycles were studied as phenomena independent of capital market imperfections. Macro faced widespread criticisms from within and outside economics. In fact, back in its last issue of 2013, five years later, The Economist put it in the following terms:

> “Mainstream macro models fail to represent some of the most basic realities of the financial system. One reason is that doing so is hard. Another is that for a long time it did not seem to make much difference. In the absence of crises, the activities of the financial sector can appear irrelevant for long stretches of time. Small wonder

so many academics model the economy as if banks and other intermediaries simply do not exist. The crisis, which was completely unanticipated by the vast majority of academics and policymakers, revealed some of the drawbacks of these shortcuts. ”
(The Economist, 2013)

There was much truth in that comment. On my part, the weekend of the fall of Bear Sterns, March 2008, I recall discussing its implications with some Wall Street acquaintances---I still think it is a good exercise for a macro student to translate Wall Street language into modeling language. Much of the conversation had to do with what the Federal Reserve had to do to restore market liquidity. I was embarrassed that by my second year, I couldn't even define market liquidity![1] Macroeconomics, of course, reacted by quickly developing models where financial market imperfections are the epicenter. Today, we have many graduate students working on the subject, a thriving Macro-Finance Society, and multiple NBER working groups dedicated to the subject. This work has been very influential in practice.

In my case, I was fortunate that Mark Gertler taught his financial accelerator model (Bernanke and Gertler, 1989a; Bernanke et al., 1996) during the last module of a course entirely dedicated to the new-Keynesian framework. After the last lecture, during the summer of 2008 I began surveying some of the few existing models with financial frictions—the sequence of papers by Allen and Gale (1998, 2000), Holmstrom and Tirole (1997, 1998), Kiyotaki and Moore (1997), Bernanke and Gertler (1989b); Bernanke et al. (1996) and Caballero and Krishnamurthy (2001) and some others.[2] I identified a void.

What causes contractions in liquidity? Can contractions in liquidity quantitatively explain business cycles? I began working on Bigio (2015, AER) during my third year, the fall of 2008. I was motivated by the idea that the 2008-2009 financial crisis began with an abrupt collapse in the funding of many businesses sectors. The papers I surveyed had focused on limited enforcement (or moral hazard) in investment projects carried out by entrepreneurs that lack assets. Yet, when we think of operating firms and business cycles, it seems evident that most of the capital stock is worth many multiples of their investment flow.

[1] Actually, I think it's a problem that we don't have a proper mathematical definition of liquidity. Here is mine. Liquidity as a property of an asset. an asset is liquid if gains from trade are sufficient conditions to guarantee trade. Depending on the context, the volume of trade is a measure of liquidity, but in others, volume is meaningless.

[2] I actually went directly to buy Jean Tirole's Corporate Finance Textbook after that class.

For that reason, I began to investigate frictions that could prevent firms from using their existing capital stock to finance their investment flows—frictions that would endogenously reduce the liquidity of their capital stock. I saw Kiyotaki and Moore (2008, whose final version was published at the JPE two decades after the first draft) as a good approximation to what was going on. In Kiyotaki and Moore, limited enforcement prevented agents from transacting solely with repayment promises so firms sell a fraction of their past stock to finance new investment. However, in Kiyotaki and Moore the liquidity of the capital stock is exogenous. At the time, the view among practitioners was that the financial crisis stemmed from problems of asymmetric information in valuing collateral. It occurred to me that recessions could be periods where the heterogeneous returns to existing capital fan out. After all, recessions are periods with a lot of churning. If returns to capital are private information, this determines the liquidity of capital endogenously. The idea was so natural that a similar model was developed independently (Kurlat, 2013).

In Bigio (2015), there is a continuum of capital units whose returns are private information. Working with a continuum is convenient because one can derive marginal conditions. In Bigio (2015), I encountered a formula that determines the marginal asset sold under asymmetric information, for asset qualities $\lambda \sim F$. The marginal asset sold $\lambda^{\star}$ is given by following marginal condition:

$$\underbrace{\frac{\lambda^{\star}}{\mathbb{E}_F\left[\lambda|\lambda < \lambda^{\star}\right]}}_{\text{lemons premium}} = \underbrace{\left(1 + r\left(\mathbb{E}_F\left[\lambda|\lambda < \lambda^{\star}\right]\right)\right)}_{\text{marginal value of liquidity}}$$

The lemons premia is the ratio of the internal valuation of the marginal asset relative to the average valuation of in the pool of sold assets. In equilibrium, the premium must equal the marginal value of relaxing financial frictions with a marginal unit of funding—r encodes the value of relaxing constraints as in Kiyotaki and Moore. Naturally, the balance tilts towards less liquidity when the asset-quality distribution becomes more disperse, providing a theory of time-varying liquidity. In a business cycle model, a contraction in liquidity translates into less production, which can occur even if the production possibility frontier is untouched.

In parallel to developing the techniques to incorporate asymmetric information into business cycle models in Bigio (2015, AER), I wanted to understand the quantitative bite of liquidity shocks in Kiyotaki and Moore. The results eventually became a paper co-written with my graduate student, Andres Schneider, now at the Board of Governors of the Federal Reserve. Bigio and Schneider (2017, EER) makes a surprising but simple point:

without additional strong amplification mechanisms—such as sticky prices or strategic complementarities—models with financial frictions on investment cannot account for a decline in output of the magnitude of the Great Recession.[3] The reason is simple: investment is such a small fraction of the capital stock that even if we shut down investment entirely for a year, the displacement of the production possibility frontier is too small to account for significant recessions.

It became evident that the macro-finance was directly importing off-the-shelf models from corporate finance but was having difficulty producing quantitatively significant business-cycle fluctuations. If you write about corporate finance, you probably want to talk about financing large investment projects, where finance matters most for firms. For business cycles, we needed something extra.

I was reluctant to add an amplification mechanism—like sticky wages—because amplification mechanisms amplify all shocks, including policy shocks that can correct financial shocks. Why should macro-finance develop into an independent subfield if financial shocks are like other shocks? Learning from the production of Bigio and Schneider (2017), I decided to give it a shot at adding funding needs in labor hiring decisions in Bigio (2015). Changing the location of frictions produces strong output responses, even from mild increases in capital-quality dispersion. With that structure, Bigio (2015) can replicate the output and investment pattern observed during the Great Recession.

An unappealing feature of Bigio (2015), and other models like that, is that capital has to be sold. In practice, firms *pledge* assets as collateral. To be honest, I heard this criticism in seminars. This got me to think on why firms pledge collateral instead of selling it. I began working on this question with a UCLA student Liyan Shi, from the Einaudi Institute and the Tepper School at Carnegie-Mellon University. In Bigio and Shi (2021, currently being revised for Restud) we argue that in asset markets with asymmetric information, pledging collateral, which is akin to singing repos, is a natural resolution to adverse selection. As in Bigio (2015), we consider a market where borrowers require funds but have private information about existing assets but, different from Bigio (2015), lenders offer repurchase options. We consider a market where, as in Bigio (2015), borrowers require funds to relax financial constraints but have private information about other existing assets but, different from Bigio (2015), lenders offer repurchase options. We characterize the equilibrium in a competitive market for repos. Repos resolve the adverse-selection problem in the sense that all assets are used and no asset remains idle as with outright sales. However,

[3] Bigio and Schneider (2017) also argues that the asset pricing implication of such models was counterfactual: a scarcity logic applies in those models and thus, the price of capital increases when liquidity limits the amount of investment. Both points are shared in common with contemporary work by Shi (2015).

competition induces inefficient cream-skimming. The equilibrium contract actually has a closed form for the amount of liquid funds, x, that replaces the formula above. This formula is

$$x = \mathbb{E}_f \left[\min \left\{ \lambda, f^{-1} \left(\frac{r(x)}{1 + r(x)} \right) \right\} \right].$$

The formula is portable to many other applications.

How do contractions in liquidity get amplified by production networks? I met Jennifer La'O during her job-market talk at NYU in 2010. La'O was studying the connection between noisy information and financial frictions. We agreed that existing financial frictions models, those focused on the investment margin, had difficulty generating business-cycle fluctuations.

Focusing on labor, as in Bigio (2015, AER), can generate large fluctuations but financing premia are too high. So that was one problem. Meanwhile, some papers were challenging the idea that a credit contraction on firms was quantitatively meaningful. We had both seen a presentation, Chari and Kehoe (2009), which showed evidence that at least for the aggregate firm, corporations could finance their total capital expenditures with retained earnings (see also Zetlin-Jones and Shourideh, 2012). So that was another challenge. La'O and I wanted to respond to the challenges. We began thinking about inter-firm linkages. Our thought was that with firm linkages, financial shocks that only impact a subsector could spill over to other sectors through supply and demand channels. What could be interpreted as small contractions in liquidity, with small credit spreads, could add up when aggregating over the entire economy. This approach would produce the meaningful quantity fluctuations with small prices fluctuations that we were looking for and answer to Chari and Kehoe that financing of intermediates and not investment is where to look for financial constraints.

We had recently seen the study on the amplification of TFP shocks in production networks Acemoglu et al. (2012, ECMA) and began exploring how we could introduce wedges due to financial networks into production networks. This project eventually became Bigio and La'O (2020, QJE). In Bigio and La'O we consider a static, multi-sector, general equilibrium model of inter-sectoral trade. We introduce exogenous wedges that distort the input choices of firms.[4] The paper is about how those sectoral distortions aggregate. We show that distortions manifest in total factor productivity (TFP) and in a labor wedge that does not appear in Acemoglu et al.. Near efficiency—or equivalently, for moderate funding

[4]These distortions may be also rationalized as the result of marginal tax rates or monopolistic markups, but our original motivation were working capital constraints.

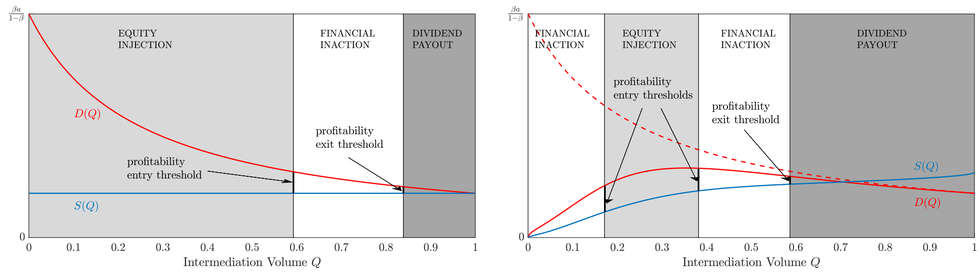
spreads—distortions are of second order for aggregate TFP, but first-order for the labor wedge. The impact of sectoral shocks on the labor wedge is proportional to the sectoral sales relative to GDP (Domar weights). The first part was no surprise because productive efficiency is maximal when distortions are zero. However, distortions drive wedges between sectoral prices and marginal costs, the effects of these wedges compound. At the aggregate level, the price of the final consumption good is distorted away from its marginal cost of production, and a labor wedge arises.

That paper ends with a quantitative exercise motivated by our original thoughts. We feed the model with sectoral-level credit spreads obtained from Gilchrist and Zakrajšek (2012) and demonstrate that financial distortions can indeed explain a large portion of decline in output of the Great Recesssion. For that, the model needs a labor-supply elasticity close to those used in the business-cycle literature. In retrospect, a limitation of Bigio and La'O that we work with a intermediate-input elasticities of substitution equal to 1, which gives economies much flexibility—at least at business-cycle frequency—making the labor wedge primary transmission mechanism. In some sense, the business-cycle amplification is not that satisfactory because with a standard labor-supply elasticity used in the business-cycle literature is a stand in for other frictions. To our original motivation, I think our paper was a good starting point, but I think that work that developed around that time, Baqaee and Farhi (2019) in particular, which departs from unit intermediate-input elasticities, provides a more promising and comprehensive framework.

How does the financial sector amplify contractions in liquidity? Why are recoveries from financial crises so slow? And why is it that the financial sector has a hard time raising equity during crises? By 2012, it was evident that the Great Recession was different from other recessions. In fact, financial crises cause deeper recessions and slower recoveries (see Cerra and Saxena, 2008; Reinhart and Rogoff, 2009). We can relate these crises to some initial bank equity losses and the subsequent dynamics of bank equity after that. I recall listening to an interview with the Chairman of the Federal Reserve, Ben Bernanke, who was asked when the crisis would end, he answered, "When banks start raising capital on their own."[5]

In the aftermath of the Great Recession, several papers had already incorporated intermediaries into business cycle models—(see for example Gertler and Kiyotaki, 2010; He et al., 2010; Gertler and Karadi, 2011; Brunnermeier and Sannikov, 2014). However, in all of those models, the aftermath of crises are periods of high excess returns for banks because

[5] "The Chairman," *60 Minutes*, CBS News, March 15, 2009.



(a) Symmetric Information (b) Asymmetric Information

Figure 1: Financial Intermediation w/ and w/o Asymmetric Information

a logic of scarcity applies—the scarce resource, equity produces high returns. In my view, this still represents a problem for this literature because it implies that periods of banking crisis should be periods where banks should raise capital faster or are periods of extraordinary returns that lead to fast recoveries. Furthermore, these are models where there is nothing special about banks, whereas, in reality, banks issue liabilities that are means of payment and are only intermediaries.

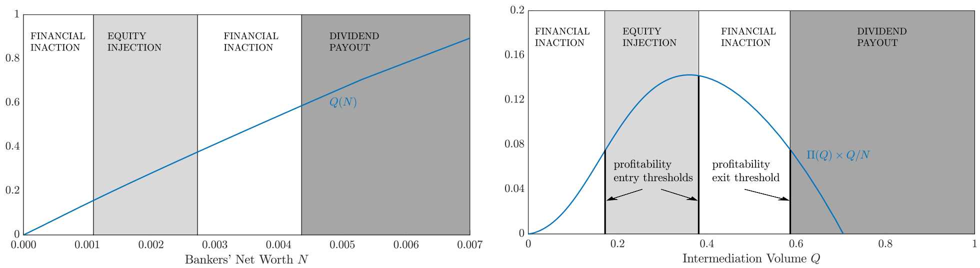
For my job market paper, I decided to address the challenge of writing a model where bank returns are low, and there is something special about bank intermediation. I wanted to think on a theory where more profound crises lead to slower recoveries. I embraced the view in Gorton (2012), I still do, that the central role of banks is to create securities that are immune to adverse selection. That paper eventually became a much more elegant paper Bigio and D'Anvernas (AEJ Macro, forthcoming) after my student at UCLA, Adrien D'Anvernas (now at Stockholm School of Economics) became my co-author.

We illustrate the underlying mechanism with some graphs. As with any intermediary, a financial intermediary is an agent that buys from the supply schedule and sells to the demand schedule.

In the two panels of Figures 1, the two curves represent aggregate demand and supply schedules $D(Q)$ and $S(Q)$, respectively, given an intermediated quantity Q. The intermediaries' marginal profit is simply $\Pi(Q) = S(Q) - D(Q)$. If some friction limits the volume of intermediation, Q, there is a positive arbitrage. In models with financial intermediaries, a multiple of net worth caps Q.

The shapes of the demand and supply schedules govern the behavior of marginal profits. In the left panel, marginal profits decrease in Q without information asymmetries and thus return to bank equity, as depicted in the left panel of 2.

Marginal profits influence the evolution of net worth in two ways: directly, by affecting



(a) No Asymmetric Information (b) No Asymmetric Information

Figure 2: Marginal Profits per Unit of Net Worth and Equity Injection Decisions

retained earnings, and indirectly, by attracting outside equity injections. If equity is large and marginal profits are low, banks pay out dividends because the return is low. The opposite occurs whenever net worth is below a threshold, and equity injections, attracted by returns, replenish net worth. Because the entry and exit profit levels are not the same, there is an intermediate equity inaction region. Within that region, equity can increase, but only through retained earnings. If shocks reduce bank net worth, the logic applies, and equity injections and retained earnings operate as a stabilizing mechanism.

Asymmetric information alters this stabilizing force. When intermediaries purchase capital under asymmetric information, both the quantity and the quality of assets increase with the purchase price, and the effective demand is backward-bending. A direct consequence of this backward-bending demand is that marginal profits are not decreasing, as in the left of panel 2. Instead, marginal profits are potentially hump-shaped, as in the right panel. The hump shape in marginal profits generates two inaction regions instead of the single region in 2.

The inaction regions impair the stability of financial intermediation. A shock that produces small equity losses that only send the economy to the injection region is stabilized when information is symmetric. If losses are significant, the economy enters the leftmost inaction region, and the economy loses its tendency to return to equilibrium.

All in all, this is a model where size matters. Large shocks capsize the economy, but small ones are stabilized. Bigio and D'Anvernas is a fully-fledged general equilibrium version of this logic.

Bigio and D'Anvernas shaped how I view banks. As I noted above, financial-crises models are not explicit about why banks exists nor say anything about why banks are different from other firms. I'm a monetarist because I believe money plays an essential role in the economy. And I believe that banks are unique because their liabilities are money: In practice, when a bank makes a loan to a business owner, the bank acquires an asset, and, in exchange, the borrower receives a deposit. Deposits are different from any other financial liabilities because they circulate. Deposits circulate as business owners exchange loans for bank liabilities. They use these liabilities to pay workers, workers to make further purchases, and so on.

Furthermore, deposits circulate within the banking system. We do not have to worry about which bank issued what liability when we accept payments. Banks settle that for us, and we do not know what happens behind the scenes. We just now in which bank our deposit account is. These observations suggest that the creation of circulating liabilities has a significant social value. Yet, when we turn to classic models in banking Diamond and Dybvig (1983); Diamond (1984); Williamson (1987); Boyd and Prescott (1986) these theories leave aside almost entirely the notion that bank liabilities are the primary medium of exchange.

In ongoing work with my UCLA colleague, Pierre-Olivier Weill, (Bigio and Weill, 2021) we study theoretically why bank deposits are money. We start from the premise that many assets in the economy cannot circulate because of asymmetric information, but others could, at least in principle. We think of banks as financial institutions that purchase these illiquid assets in exchange for their liabilities, which do circulate. Since illiquid assets back bank liabilities, liabilities could also suffer from asymmetric information. We argue that banks exist to structure liabilities stripping off their information content to guarantee their circulation, an idea due to Gorton and Pennacchi (1990) that also motivates the ad-hoc financial arrangement in Bigio and D'Anvernas (AEJ Macro, forthcoming). We develop this idea in general equilibrium and derive implications regarding the provision of safe assets by the government, the regulation of bank liabilities, and implications for bank-competition policy.

How does monetary policy affect bank liquidity and why that matters for the supply of credit? Monetary policy also changed during my doctoral dissertation. During 2008, the interbank market froze. Banks responded by slashing new credit as these events unfolded. The world was fortunate to have a financial economist and historian, Ben Bernanke, as a Chairman of the Federal Reserve. I say the world was fortunate because by 2008, the leading theoretical framework for monetary policy analysis, the New Keynesian model, abstracted completely from implementation issues, had no notion of an interbank market and its direct influence on credit markets. In theory and practice, the dominant paradigm was to focus policy on a sole instrument, the nominal interest rate.[6]

[6]The textbook treatment of the New Keynesian model (e.g. Woodford, 2004; Galí, 2015) followed the dictum in Woodford (1998) that monetary policy can be analyzed without money. Even within the New

Bernanke had the vision to intuitively think beyond what-interest-to-set-next and carried out an unprecedented private-asset purchase program. It was bold because the fiscal and inflationary consequences were uncertain.

By my graduation in 2012, banks had accumulated large amounts of central bank reserves without a substantial expansion in lending. Not surprisingly, the role of banks in the monetary policy transmission was at the center stage of policy discussions (see Keister and McAndrews, 2009). There was no modern macroeconomic model that explicitly modeled the implementation of monetary policy through the banking sector.

That year Javier Bianchi visited NYU. After discussing the issue, we began working on a tractable general equilibrium model that could articulate the credit channel of monetary policy and its implementation through the supply of reserves to the banking system. Liquidity management lies at the heart of Bianchi and Bigio (forthcoming).

Bank portfolios in Bianchi and Bigio are composed of deposits, loans, government bonds, and reserves. When a bank grants a loan, it simultaneously issues deposits and gains intermediation profits. However, deposits circulate. When a deposit is moved out of a bank, another bank absorbs that liability. As occurs in practice, that transfer is settled with reserves because loans are illiquid. I think Bigio and Weill (2021) are a foundation for why deposits circulate. The beautiful paper by de de Cavalcanti et al. (1999) captures well why banks settle with reserves. Bianchi and Bigio take this architecture as given and treat deposit withdrawals as unpredictable. If a deposit withdrawal is too large, the bank ends short of reserves. The bank can sell bonds in exchange for reserves, but this may not be enough to tap its deficit. At that point, the bank must incur the expense of borrowing reserves, either from the discount window at a penalty rate or from the interbank market. Because the interbank market is over-the-counter (OTC), possibly because not all banks trust each other, the probability of finding a counterpart in the interbank market depends on the scarcity of reserves. Thus, the supply of reserves affects the interbank market's trade terms affect the degree of liquidity risk. By holding a large buffer of liquid assets composed of bonds and reserves, a bank reduces its exposure to liquidity risk at the expense of intermediation profits. Monetary policy affects the supply of bank credit by affecting liquidity premia by tilting this trade-off.

Analyzing monetary policy transmission through the banking system leads to novel insights: In contrast to models in which reserve requirements exogenously determine the demand for reserves, monetary policy here affects the risk-return trade-off between hold-

Monetarist framework, scholars were interested in the properties of monetary and credit exchange, but the impact of central bank policy on bank credit was absent (see the texbook Nosal and Rocheteau, 2011).

ing reserves vis-à-vis loans. The central bank alters this trade-off through both conventional and unconventional open market operations and by setting interest rates on reserves and discount window lending. Although the composition between government bonds and reserves and the composition matters at the macro level. We show that swaps of bonds for reserves have aggregate effects on liquidity premia by altering the interbank market tightness. Moreover, by absorbing illiquid assets into the central bank's balance sheet, unconventional open market operations have more potent effects than conventional ones.

A central insight of the paper is that the implementation of monetary policy matters: interest on reserves and the central bank's balance sheet constitute independent policy instruments. Crucially, we show how configurations that achieve the same target for the interbank market rate generate a different lending rate and pass-through. In particular, configurations with a larger balance sheet induce a larger credit supply and a higher pass-through from the interbank-market rate to the lending rate. These findings imply that the questions on setting a target for the policy rate and how to implement it must be analyzed together.

An application of that paper is to examine the credit crunch during the U.S. financial crisis after 2008. Back then, it was not clear why banks were holding so many reserves without extending loans. Joseph Stiglitz argued that the significant equity losses of 2008 were to blame, whereas Robert Lucas Jr argued that the interbank markets was jammed. Martin Feldstein wrote an op-ed arguing that paying interest on reserves was responsible and a policy mistake. Others blamed capital requirements, others the "obvious" lack of demand, and others the "obvious" lack of credit worthy borrowers. In Bianchi and Bigio we devise a procedure to reverse engineer the shocks needed to discern this importance of these conflicting stories. The key finding is that disruptions in the interbank market played a substantial role around the time of the Lehman Brothers bankruptcy but by 2010, the loan demand and credit worthiness became the dominant factors. I believe this finding calls for a "not-so-obvious" theory where an initial credit crunch eventually becomes a demand crisis.

Many authors contemporaneously embarked in related projects regarding the transmission of monetary policy through banks creating a thriving area of research. For example, Piazzesi and Schneider (2018) focus on the connection between settlement payments and securities prices with an emphasis on the price-level determination, Drechsler et al. (2017) study the effects of imperfect competition in the deposit market, De Fiore, Hoerova and Uhlig (2018) study the role of collateral assets and others introduce these features into models with nominal rigidities (Arce, Nuño, Thaler and Thomas 2019; Piazzesi, Rogers and Schneider 2019). Jointly with Javier Bianchi and Charles Engel (University of Wisconsin, Madison), we have been working on a multi-currency version of Bianchi and Bigio. In Bianchi et al. (2021) we connect the implementation of monetary policy, the special value of the dollar in international payments, the UIP and CIP deviations, and the determination of exchange rates.

The most important insight of Bianchi and Bigio is that central banks have more tools than conceived by conventional wisdom. On the one hand, interest-rate targets grant control over inflation, but the supply of reserves grant control over credit spreads. By adequately choosing open-market operations (OMO) and setting policy rates, central banks can target inflation and the volume of credit in the economy.

Thanks to a visit to Princeton in 2016, I met Yuliy Sannikov (now at Stanford GSB). We began thinking of the normative implications of this insight in an incomplete market monetary economy. In Bigio and Sannikov (2021) the central bank can operate in three regimes: in a corridor system where it has control over interest rates and credit spreads, a satiation regime where the transmission channel is the new-Keynesian model, and a liquidity trap regime, where credit spreads are zero, OMO are neutral, but reductions in interest rates beyond a negative value are recessionary.

A message that emerges is that the central bank balance should operate with a small balance sheet during booms but expand its balance sheet, operating in a floor system, during busts but should never drop rates past the negative point where they trigger a liquidity trap. This recommendation results from a complex policy tradeoff that I summarize with the flow chart in . The smaller the central bank balance sheet, the higher credit spreads—as in the first flow. Credit spreads, altered through OMO, have direct effects through the credit channel—the second flow. By affecting credit, spreads can enhance the effects of the standard instrument and increase the stabilization power of MP—the flow labeled Power in the Figure. By tightening credit, MP can also mitigate the impact of aggregate shocks, a standalone macro-prudential effect. The stabilization power and the macro-prudential benefits contribute to overall macro insurance. The tradeoff is that increasing credit spreads reduces insurance against idiosyncratic shocks.

There are undoubtedly many other applications and open questions. The last decade has witnessed dramatic increases in their balance sheets—see the Figure below. Central banks have innovated creating tools that involve different open-market operations on various asset classes and the use of differentiated reserves requirements, SWAP lines, repo agreements, currency swaps, and different forms of indexation. Monetary theory is lagging behind central bank practice, but it opens the door to many exciting explorations.

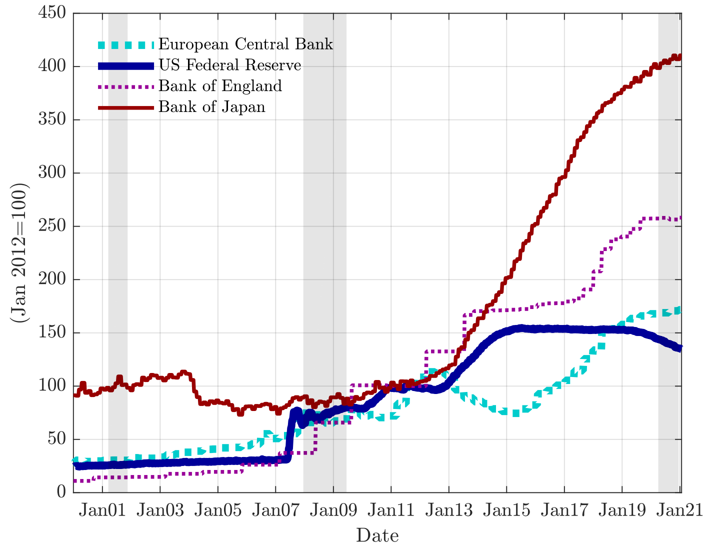


Figure 3: Total Asset Holdings of Major Central Banks

Some departures. As I mentioned in the first passage of this essay, sometimes you don't know where economic exploration will take you. When trying to calibrate the models in Bigio and D'Anvernas and Bianchi and Bigio, I stumbled with the reality that there is no obvious way to calibrate financial intermediary models. In 2014, I met Juliane Begenau (now at Stanford GSB), whose job-market paper, Begenau (2020) was also on the topic. We agreed that it is not obvious what equity measure—book or market equity—is a good model counterpart and what financial frictions are the most realistic (of course, other scholars have recognized this difficulties Adrian et al., 2012; He et al., 2010; Adrian et al., 2014). We began to work with two now-former students, Jeremy Majerovitz, a graduate student from MIT, and Matias Vieyra from the Bank of Canada, to answer these questions. The starting point in Begenau et al. (2020) is to collect some facts about bank Tobin's Q, which provides a unifying theme to answer those questions. That paper brings together four facts:

1. The time-series behavior of Tobin's Q reflects that bank book and market values diverge during crises.

2. Market equity captures information not contained in the book because Tobin's Q has predictive power.

3. The cross-sectional dispersion of Tobin's Q increased during a banking crisis.

4. Individually, Tobin's Q and market-leverage are slowly mean-reverting after a shock to net worth.

We argue that the most prominent models with intermediaries cannot jointly deliver these facts (Gertler and Kiyotaki, 2010; He et al., 2010; Brunnermeier and Sannikov, 2014). In the paper, we argue that both market and book equity measures matter and present a model with delayed accounting that matches all facts.

A final example of cross-paper spill-overs is Bigio et al. (2021) joint work with Juan Passadore of the Einaudi Institute and Galo Nuño from the Bank of Spain. This paper studies the optimal maturity of public debt. On the surface, this topic has nothing to do with the agenda I described above. This paper makes two conceptual innovations relative to public finance. First, we highlight the role of liquidity frictions, the notion that markets for bonds of different maturity are segmented. The same frictions inspire these frictions in the interbank market of Bianchi and Bigio. As a result, quantities impact prices. The second innovation is introducing an arbitrary number of bonds and dealing with dynamic optimization working with a density. This optimization is technically similar to studying optimization in heterogeneous agent models, as in Nuno and Moll (2018), a technique that I became familiar with while working on Bigio and Sannikov (2021). In Bigio et al. , we derive a simple principle that guides the optimal issuance of bonds of a given maturity:

$$\frac{\text{issuance at maturity } \tau}{\text{GDP}} = \frac{1}{\text{liquidity coefficient at maturity } \tau} \times \text{value gap at maturity } \tau \, .$$

The principle states that in a given period, the issuances of a bond of a given maturity (relative to GDP) should is given by the product of a value gap and a liquidity coefficient. The value gap is the difference between the market price, or asset-pricing kernel, and the internal valuation of a bond, an internal pricing kernel, as a percentage of the price. In this model, pricing kernels are not equalized because of the liquidity frictions. The paper maps different economic forces to movements in the value gap to describe how the maturity of public debt should impact the maturity and we calibrate it to evaluate Spain's debt management practices, to illustrate the point.

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PAPERS & WORK IN PROGRESS

The table below lists the papers in this statement.

Paper	Coauthors	Status
Liquidity and Asymmetric Information		
Endogenous Liquidity and the Business Cycle	—	Published at AER 2015
Financial Frictions in Production Networks	La'O	Published at QJE 2020
Liquidity Shocks and the Business Cycle	Schneider	Published at EER 2017
Repos in the Market for Lemons	Shi	being revised for Restud
Money and Banking		
Financial Risk Capacity	D'Anvernas	Forthcoming AEJ:Macro
Liquidity Management and Monetary Policy	Bianchi	Forthcoming Econometrica
Speculation and the Business Cycle	Zilberman	Reject and resubmit for Restud
A Q-Theory of Banks	Begenau, Majerovitz, Vieyra	Submitted 2021
A model of credit, money, interest and prices	Sannikov	Submitted 2021
Optimal Debt-Management with Liquidity Costs	Nuño and Passadore	Submitted 2021
Scrambling for Dollars	Bianchi and Engel	Work in progress
Transfers vs. Credit Policy	Zhang and Zilberman	Work in progress
A Theory of Bank Balance Sheets	Weill	Work in progress