The Impact of Monetary Policy, Sterilised Forex Intervention, Demand and Supply Shocks on Credit in Uganda.

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Abstract

This thesis presents four chapters on monetary and financial stability policies in Uganda. The objectives address a number of research questions that have emerged following financial sector reforms and a change in monetary policy framework in Uganda.

The first chapter considers the impact of monetary policy tightening on the sectoral composition of banks' loan books in Uganda. It also investigates for evidence of a balance sheet transmission channel and tests whether some sectors in the Ugandan economy are disproportionately affected by monetary policy. I document that a balance sheet channel is present, and the real estate and agricultural sectors of the economy are disproportionately affected by the policy. The results also indicate that bank capitalisation level is vital in the monetary policy transmission process as banks with larger capital are in position to have better loan portfolio re-balancing across the sectors.

In the second chapter I investigate whether sector borrowing channel exists in Uganda. Results show that bank lending and sector borrowing channels are operational in Uganda in all currencies. As highlighted by Khwaja and Mian (2008), the existance of sector borrowing channel in Uganda improves the efficacy of monetary policy. Although we have observed that a sector borrowing channel is at work in Uganda, the role of the banks is important. We note regional and non-DSIBs banks' borrowers can offset the impact of credit supply shocks in both local and foreign denominated currencies loans. However, local banks' borrowers are unable to

offset shocks in local and foreign denominated currencies borrowing. This may indicate that these sectors resort to borrowing from non-bank sources. In addition, all types of banks are more responsive to credit supply shocks, if loans are in foreign currencies this could affect the transmission of monetary policy.

In the third chapter I study the impact of sterilised FX intervention on credit growth in Uganda, in a banking environment characterised by capital and leverage constraints. I find sterilised FX interventions dampen credit growth for a period of about six months and after which it recovers. Evidence of a crowding-out channel is observed however, a exchange rate transmission channel is insignificant. These results support a case for the use of FX interventions as financial stability instruments. However, this may need further investigation as a need to balance this tool with other macro-economic policies.

In final chapter we examine using a network approach, the transmission of idiosyncratic credit supply shocks to aggregate volatility in a developing economy. In demonstrating the implications of our theoretical results in an empirical application to Uganda, the empirical results suggest that idiosyncratic shocks to credit supply account for more than a third of the volatility observed at the aggregate level. Results show that configuration of the network plays a marginal part in determining aggregate volatility, whereas the architecture of financial intermediation has a bigger effect. The Herfindahl index is no longer a sufficient statistic for explaining the banking sector's contribution to aggregate volatility.

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Declaration

I declare that this thesis is my own work, and has never been submitted to any university or academic institution for award of any degree(s), or other qualification(s). The first three empirical studies herein are solely based on my research. The fourth chapter entitled, Credit supply shocks and aggregate Volatility: A network approach is joint work between me, Prof. Stefan Niemann and Prof. Christian Ghiglino, and where applicable, I have endeavoured to clearly referenced all work due to others.

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Chapter 1

Introduction

Since the early 1990s Uganda has undertaken a number of financial sector reforms that include enhanced prudential regulation, measures to increase competition, diversification of financial products, and the encouragement of deposit mobilisation. Additional measures have included efforts in addressing informational asymmetry by establishing credit reference bureaus, financial literacy schemes and financial consumer protection guidelines. All these policies were geared towards correcting consequences of misguided financial policies in the previous period.

In line with the above reforms, in July 2011, the Bank of Uganda adopted an Inflation Targeting Lite (ITL) from the Monetary Targeting Framework (MTF) under which monetary policy was previously operated. The central bank moved to a price-based monetary policy regime that was expected to influence interest rates in the economy. In this new framework, the Bank sets policy interest rate (Central Bank Rate (CBR)) with aim of influencing the 7-day interbank rate. From the start, the new monetary policy framework was set in an environment where inflation was high and the financial sector dominated by the banking sector. This has led to a number of research questions that I explore in this thesis. In its four chapters, the thesis covers monetary and financial stability policies research questions.

In the first chapter I examine the impact of monetary policy tightening on the sectoral composition of bank's loan portfolio following a change in monetary policy framework in Uganda. The chapter investigates for evidence of a balance sheet transmission channel and considers whether some sectors of the economy are disproportionately affected by tight monetary policy. Under the inflation targeting monetary policy framework, credit transmission mechanism is important, although it not extensively studied. Banks form an integral part of the transmission system as they are the largest part of the financial system in Uganda and help implement the central bank's operation guidelines. I document that a balance sheet channel is operational and the real estate and agricultural sectors of the economy are disproportionately affected by the policy.

In the second chapter, I consider whether there is a sector borrowing channel in Uganda. Is the inability of a borrowing sector(s) to smooth the impact of credit supply shock by borrowing from alternative funding sources in our case these are other banks in the bank system. This requires us to simultaneously disentangle bank lending channel from sector borrowing channel. In this approach we have to separate demand and supply shocks as these are usually affected by similar factors.

As the Ugandan economy liberalised financial, capital and exchange markets, the local currency has been subject to both depreciation and appreciation pressures. As a policy the central bank has carried out foreign currency interventions as in an effort to address excessive exchange rate volatility, and manage monetary policy stance, as well as foreign reserves accumulation. However, evidence in support of regular intervention in the foreign market is still limited. This naturally leads us to the third chapter, where we investigate the impact of foreign exchange intervention on credit growth in Uganda. I find sterilised FX interventions dampen credit growth. The crowding-channel is the main transmission mechanism at work and the exchange rate transmission channel is insignificant.

In the final chapter, we develop a theoretical model embedded with financial frictions and empirically consider how idiosyncratic microeconomic shocks from the banking sector are propagated to the real economy. We find the bank Herfindahl index is no longer a sufficient statistic to account for the banking system's contribution to aggregate volatility. The configuration of the production network plays a marginal part in determining aggregate volatility. However; financial intermediation has an important role in amplifying microeconomic shocks to the real economy. We finally find due to granularity and propagation mechanism via the intermediation and production network, bank-level supply shocks have sizeable real implications.

Chapter 2

Monetary Transmission Mechanism in Uganda, evidence from banks' sectoral lending data

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Abstract

The paper considers the impact of monetary policy tightening on the sectoral composition of banks' loan books in Uganda using banks' quarterly sectoral lending data from 2011Q4 to 2016Q4. The central bank adopted a new monetary policy framework and operated a restrictive monetary policy during this period. The paper investigates for evidence of a balance sheet transmission channel and tests whether some sectors in the Ugandan economy are disproportionately affected by monetary policy. An initial analysis considers whether relationships exists between the policy rate and various sectoral lending compositions using Vector Auto-regression (VECM) model. A further analysis is carried out using a generalised method of moment(GMM) dynamic panel estimator as defined by Blundell and Bond(1998). Results suggest that long and short run relationships exist between the policy rate and the sectoral lending variables. A balance sheet channel is present, and the real estate and agricultural sectors of the economy are disproportionately affected by the policy. The results also indicate that bank capitalisation level is vital in the monetary policy transmission process as banks with larger capital are in position to have better loan portfolio re-balancing across the sectors.

2.1 Introduction

In this paper we explore the impact of monetary policy tightening on the sectoral composition of banks' loan books in Uganda and its effect on some banks' attributes. Efficacy of monetary policy requires policy instruments used by the central bank to be effective in controlling aggregate demand in the economy. In developing countries like Uganda, it is argued that the link between the policy instruments and aggregate demand is weak in comparison to what is observed in developed and emerging countries (Mishra and Montiel (2013)). Financial structures of developing economies make the banking channel a dominant channel of monetary policy transmission whose effectiveness will largely depend on the structure of the banking system (Mishra and Montiel (2013)).

This is further compounded by the relationship between monetary policy actions, availability and cost of credit in developing countries that is said to be weak, due to a lack of competition in the formal financial sector as changes in banks' costs of funds tends to feed into banks' profits rather than the supply of banking credit (Cottarelli and Kourelis (1994)). In Uganda the financial sector is dominated by the banking sector that accounts for about 80 per cent of total assets of the financial system. The Ugandan banking system had 25 banks, of which 3 were considered domestic systematically important banks and controlled about 39 per cent of the total bank assets and 38 per cent of the total banking lending as at the end of June 2016. This suggests the financial sector is highly concentrated, with a few banks controlling a large proportion of credit extension, which may hinder the monetary transmission process.

Under the newly implemented monetary policy framework "inflation targeting", the credit transmission mechanism is increasingly relevant in Uganda, although it is not extensively studied. In inflation targeting, monetary policy is implemented through interest rates. Banks are, therefore, an integral part of the transmission mechanism as they make up the largest part of the financial system in Uganda and help implement the Central Bank's guidelines. To the best of my knowledge, the only paper that has considered this subject is a paper by Abuka, Alinda, Minoiu, Peydró and Presbitero (2015), who examine the impact of monetary policy on loans and real effects in Uganda and show an increase in interest rates reduces supply of bank credit. Having highlighted some of the features of monetary policy transmission in developing countries, analysing the impact of monetary policy in Uganda, is considered as monetary policy is now pivotal in this developing country. From a policy perspective, it has been widely observed that restrictive monetary policy can be discriminatory in nature. Dedola and Lippi (2005) used dis-aggregated industrial data of five developed economies and report significant differences across industries that arise from monetary policy effects. A further implication of this observation would suggest that caution is required when monetary policy is used.

Empirically works of Bernanke and Blinder (1992a) and Christiano, Eichenbaum and Evans (1996) posits that monetary policy has a short-run effect on the real economy. The credit channel theory was advanced as an alternative explanation for the short-run effects of monetary policy as opposed to the traditional "interest rate view". It stipulates an increase in short-term nominal interests leads to an increase in longer-term nominal interest rates hence, affecting the real interest rates. The credit channel assumes that the real economy is affected through financial frictions between borrowers and lenders in the financial markets. Literature suggests two different monetary policy channels operate under the credit channel, namely: the "balance sheet" channel that predicts the amount of lending offered to borrowers is disrupted when banks (lenders) get sensitive to the decreasing value of collateral and increased debt service as a result of contractionary policy. In contrast, the "bank lending" channel operates through the decrease in bank reserves as contractionary monetary policy takes effect, hence a reduction in the amount of loanable funds, since central banks directly affect the supply side of financial markets.

Weakness in Monetary Transmission Mechanisms (MTM) in developing countries have been attributed to the current empirical methods used as observed by Mishra and Montiel (2013).

In advanced economies, most empirical work on MTM use Structural Vector Auto-regressive (SVAR) and Vector Auto-regressive (VAR) models, which assume that all the transmission channels are operational.

Mishra and Montiel (2013) show most of the empirical work on MTM in developing economies rely on the same assumptions and lags in policy effects as used in the advanced economies. Initially, We use an unrestricted Vector Error Correction model(VECM) to establish existence of relationships between the policy rate and various sector lending variables. Then dynamics panel data methodology is employed, an approach based on less restrictive assumptions. The impact of banks' attributes and policy rate on the sectoral composition of loans data at bank level is considered. With balance sheet and macroeconomic variables used as controls in the analysis. The loans data, captures the volume of credit advanced and there is a need to distinguish between factors that drive supply and demand of loans. The number of loans applications variable is used to measure demand for loans in the study.

The results indicate long-run and short-run relationships exists between the policy rate and different sector lending variables. In four out of nine sectors, the results show a tight monetary policy leads to the reduction of credit advanced by these sectors. We also observe a significant reduction in credit extension to real estate and agricultural sectors. This results is plausible, as these sectors report the highest number of non-performing loans (see table A.2 in the appendix). Banks with large capital make significant diversified loan portfolio allocations. These results indicate a balance sheet transmission channel is operational in Uganda.

The paper is structured as following. Section 2.2 describes the stylised facts of the Ugandan economy, Section 2.3, provides a literature review. In Section 2.4, we consider the data problem and section 2.5 provides a data overview. Section 2.6 outlines the methodology used. Section 2.7 provides the results and Section 2.8 provides the conclusion.

2.2 The Ugandan economy at a glance

2.2.1 Monetary Policy

In the 1970s and 1980s, Uganda's monetary policy framework was used to finance government activities, subsidise some sectors of the economy and for exchange rate management. These activities led to an increase in inflation in the country. And due to these inflationary pressures that built in the economy, the Bank of Uganda (BoU) adopted the Reserve Money Program (RMP) framework in 1993 as a way of controlling the high inflation in the economy. Its objective was to maintain price stability with reserve money acting as an operational target. However, In July 2011, the Central Bank adopted the inflation-lite targeting framework; a modified version of the commonly used inflation targeting framework to meet the challenges of macroeconomic management generated by the transformation of the economy. In this new policy setting, the Central Bank sets the Central Bank Rate (CBR) to a desired monetary policy stance for a given period, usually a month. BoU then conducts Open Market Operations (OMO) to bring the CBR in line with the 7-day interbank money market rate.

2.2.2 Financial Sector

The financial sector in Uganda has undergone reforms that include enhanced prudential regulation, measures to increase competition, diversification of financial products and a boost in deposit mobilisation. The banking sector is well capitalised with average tier one capital adequacy ratio and total capital adequacy ratio recorded at 19 per cent and 21.7 per cent respectively by the end of 2016. In terms of retail funding, customer deposits contributed to about 82 per cent of the total liabilities by the end of June 2016. Although small, the interbank market and swaps market are the main sources of wholesale funding, this limits operation of the bank lending channel as market-based funding cannot be used in place of deposits. In Table

2.1, we observe bank lending across sectors and it shows the building and construction, trade and commerce sector accounted for the largest share of lending at about 24 per cent and 18 per cent respectively. The success of these reforms has been mixed; notably the system remains underdeveloped in contrast to financial systems in advanced and emerging economies.

		Jun-13	Jun-14	Jun-15	Jun-16
Manufacturing	Share	14.4	13.7	16.1	14.6
	Growth rate (YoY)	10.0	8.9	40.6	-5.5
Trade & commerce	Share	20.3	20.8	19.5	17.9
	Growth rate (YoY)	-0.5	16.9	12.8	-4.9
Building & Construction	Share	23.3	23.3	23.2	23.6
	Growth rate (YoY)	6.2	14.3	19.8	5.2
Personal & household loans	Share	13.8	17.4	15.2	15.9
	Growth rate (YoY)	-5.0	44.3	5.1	8.4

Source: Bank of Uganda.

Table 2.1: Analysis of sectoral lending

2.3 Literature review

The role monetary policy as a tool of macroeconomic stabilisation largely depends on the way its instruments, feed through to the real economy. In terms of monetary policy transmission, short-term interest rates were traditionally seen as the only channel through which monetary policy was transmitted. However, the effect of monetary policy on banking system and credit markets has recently been singled out as an additional transmission mechanism commonly known as the credit channel of monetary policy as observed by Bernanke and Gertler (1995). Due to financial market imperfections, this transmission channel is further broken up into the bank lending and balance sheet channels. In reviewing the literature, papers that use dis-aggregated data according to some balance sheet attributes or sector(s) are first considered.

In response to Modigliani-Miller(MM) logic to banking, that argues that shocks to the liability side of the balance sheet do not affect the banks' supply of loans for a given interest, Kashyap and Stein (1995) used disaggregated banks' dataset to investigate whether a bank lending channel was present in the US. The banks are split according to their asset sizes. The authors report that the banks with the smallest assets experienced difficulty substituting into non-deposit sources of funding after monetary policy changes hence, presenting evidence of a bank lending channel in the US. They further suggest that these results were not robust enough to distinguish between loan supply and loan demand shocks. We also note that the study uses a short time series which may affect the use of these results. In this paper, banks in Uganda are largely dependent on deposits as the main source of funding as deposits account for 82 per cent of their funding according to the Financial Stability Report 2016. Therefore the need to distinguish between deposit and non-deposit sources of funding is irrelevant.

Using data on US banks' attributes, Kishan and Opiela (2000) and Kashyap and Stein (2000a), examine for the presence of a credit channel and a banking lending channel of monetary policy respectively. The latter finds evidence of a credit and a bank lending channel while the former's results suggest a bank lending channel was in operation in the US following a restrictive monetary policy as small banks with illiquid balance sheets responded most to changes in policy. Kishan and Opiela (2000) note that capital and asset size was core in determining the effects of monetary policy on loan growth. It was further observed that stabilisation policy and regulatory policy were linked. The paper argues that in times of a contractionary monetary policy an inadequately capitalised banking system may suffer a disproportionate reduction in loan growth and economic growth. This observation may not be applicable for the Ugandan banking system as all the commercial banks are well-capitalised with tier one capital adequacy ratio and total capital adequacy ratios at 19 per cent and 21.7 per cent respectively (BoU 2016).

Recent papers that have studied the credit channel of monetary policy transmission, have used data at loan-applications level; this includes data on the lenders and borrowers. The benefit of this approach it has enables researchers to differentiate between changes in supply and demand of loans. However, this methodology requires very rich data sets that are not readily available.

Jiménez and Ongena (2012) investigates whether contractionary monetary policy and poor economic conditions reduce bank loan supply in the Spanish economy using banks' balance-sheet and credit register data. This resolves two identification problems of differentiating between supply and demand of loans and the separation of monetary policy effects from economic conditions. They report either higher short-term interest or lower GDP growth reduce loan growth. And banks with low capital and liquidity felt the impact of higher interest rates or lower GDP most.Also through the bank lending channel, monetary policy and business cycle effects are transmitted. In our model of the bank balance sheet channel in Uganda, we intend to use similar banks' attributes in the analysis.

Aysun and Hepp (2013) use loan-level data to investigate the significance of balance sheet and lending channels in monetary policy transmission in the U.S. Evidence of a balance sheet transmission channel is observed following tight monetary policy. The paper highlights a diminished role for the bank lending channel when banks become less dependent on deposits. However,in

Uganda banks are dependent on deposits as a source of funding. The methodology employed in this paper incorporates the borrower leverage and lender liquidity to allow for the separation of the bank lending and balance sheet transmission channels. We take a similar approach but the focus is on the balance sheet channel and use of the lender's data as opposed to using both the lenders and the borrowers. This is done to compensate for the lack of data on the borrowers.

Most of empirical work on the credit channel has been done in developed economies. In developing countries, a paper by Abuka et al. (2015) investigates the impact of monetary policy on loans and real effects in Uganda and finds evidence of an increase in interest rates reduces supply of bank credit. The paper reports evidence of a weak bank lending channel and a strong balance sheet channel in Uganda. The methodology used in this paper is closely related to the works of Jiménez and Ongena (2012) in that it combines banks' lending data with credit register data. The paper provides a good starting point for our research, although we depart in terms of techniques used and the principal question of interest.

Several authors have considered the impact of contractionary monetary policy on sectors of the economy and these include:

Dale and Haldane (1995), estimate a sectoral SVAR model for the UK and find significant sectoral differences in the monetary transmission. The approach identifies a distinct money (interest) and credit channels in the transmission of monetary policy. In using aggregated data, the paper loses some information, making it difficult to justify the handling of monetary policy instrument as contemporaneous exogenous variable to all the other variables under study. The data fails to resolve the identification problem as the paper notes, determining the relative contributions of money and credit is impossible.

Oliner and Rudebusch (1996), consider changes in investment patterns of small and large firms in the manufacturing sector in the US after monetary policy changes. After a restrictive monetary policy is implemented, the authors report evidence of a broad credit channel as investment spending is closely related to the internal funds for small firms. This close link reflects the higher premium associated with external funds. The rise in premium may indicate a deterioration in the quality of the borrower's balance sheet as lenders reduce on credit offered.

In Europe, De Bondt (1998) uses disaggregated bank balance sheet data to investigate the presence of credit channels during a period of financial liberalisation and deregulation using a VECM. Credit to the household sector was more responsive to restrictive monetary policy as compared to firms in the economy. A bank lending channel was observed in Germany, Belgium and the Netherlands, while a balance sheet channel was reported in Germany and Italy. No credit channel was observed in the United Kingdom as the minimum reserve requirement was not strict, coupled with banks' ability to find non-deposit funding sources thereby rendering the monetary transmission channel inefficient. Although the paper uses banks' holding of securities as a proxy for loans, this treatment still falls short as banks' securities holdings have an element of demand and therefore the identification problem is not resolved in the paper.

Den Haan, Sumner and Yamashiro (2007) use the vector autoregressive analysis to study portfolio behaviour of bank loans during a monetary policy tightening and report that real estate and consumer loans fall sharply, while commercial and industrial loans increase when policy is tightened. When a non-monetary downturn was considered commercial and industrial loans sharply decrease, while real estate and consumer loans hardly change. The paper supports a case for caution when tight monetary is used as it may disproportionately affect some sectors of the economy. The paper fails to distinguish between the supply and demand of loans, the identification problem.

Kandrac (2012), tests for a balance sheet channel of monetary policy in the US using banks' data and panel data analysis techniques during tight monetary policy conditions. The paper notes, banks decreased the proportion of credit extended to "small" borrowers. Smaller banks, that lend to small businesses felt the impact of monetary policy tightening most. This paper also finds support for a balance sheet effect on small borrowers rather than on small lenders.

The author notes that a balance sheet channel operates regardless of whether or not the banking lending channel exists, as this paper focuses on the balance sheet lending channel. In our paper, sectors of the Ugandan economy are considered as "small" sectors due to a lack of a similar classification and the different levels of economic development.

While some of the above papers use the SVAR/VAR methodologies to analyse the data, these techniques are known to perform poorly in measuring MTM in developing countries as the choice of an appropriate monetary policy indicator and the identification of the exogenous monetary policy shocks is difficult, as noted by Mishra and Montiel (2013). Defining an empirically observable indicator for monetary policy stance, usually identifying the intermediate target is difficult. An incorrect choice of this indicator, may fail to strip out the independent effects of monetary policy as the correlation between the instrument and aggregate demand may be affected by other variables. These have been further compounded by the weak and underdeveloped financial markets that exist in these economies. For instance, these economies are less integrated with international financial markets and are prone to foreign exchange market interventions rendering the exchange rate channel a less effective transmission channel. The poorly developed capital markets also affect the effectiveness of the traditional interest rate and the asset channel. In this paper, the limitations are noted and Kandrac (2012) approach in investigating the impact of monetary policy on sectors of the Ugandan economy is followed.

2.4 Data problem

The theory behind the financial accelerator of Bernanke, Gertler and Gilchrist (1996) argues when borrowers face high agency costs in credit markets they should receive a comparatively lower share of credit offers during an economic downturn. It also suggests that economic downturns affect the access to credit and real economic activity of high agency cost borrowers. As real interest rates increase after monetary policy tightening, asset prices decrease, making collateral used for borrowing by firms less valuable. In such situations financial intermediaries keen on maintaining healthy balance sheets will reduce on credit advanced to these less credit worthy firms hence, increasing the external finance premium. The purpose of this paper is therefore to use banks' balance sheets to identify potential transmission mechanisms through to sectors of the Ugandan economy. The data contains information on loans offered by banks to different sectors of the economy. The research question is addressed by a methodology used by Kandrac (2012).

The dependent variable is computed as sectoral share of loans advanced by each bank. Although, data on loan demand is not available we use the number of loan applications as a variable to capture loan demand. As noted by Gertler and Gilchrist (1993) who suggest that initially small firms will demand for more loans as a response to contractionary monetary policy as they try to deal with a fall in sales, these findings point to firms facing a credit rationing. In less developed financial sector we assume that these same observations hold. In addition, it is reported that firms, especially the small ones, resort to the informal banking system to meet their loan demand (Byaruhanga 2010) as banks restrict credit to these firms.

In addition, Oliner and Rudebusch (1996) show that in times of a monetary contraction the linkage between internal funds and investment tightens significantly for small firms [1] while no change was observed in the large firms. This may point to the difficulty that small firms

[1] These are the generic firms that operate in Uganda and excludes government bodies and multinational corporations.

encounter as the supply of external funds is restricted by banks, when restrictive policy is used and as such, firms resort to using their internal sources of funding. As we assume that all firms response to the increase in policy rate by demanding more credit, we would expect the lending ratios to increase. This implies that any reduction in the sectoral lending ratios, provides evidence of a balance sheet monetary policy channel. In the analysis, we investigate whether there is a relationship between the policy rate and sector lending data. And finally the data is modelled using panel data techniques.

2.5 Data

The paper uses aggregated and dis-aggregated banks' sectoral lending data. The aggregated data is a summation of all the sectoral lending of all banks and is used as a time-series dataset in the vector auto-regression model. The dis-aggregated bank level data is used in the panel data analysis and all the data is obtained from the Bank of Uganda. The lending data is made up of loans in local and foreign currencies. Foreign currency loans are converted to the local currency using the prevailing exchange rates and aggregated as our lending data. Each bank's dis-aggregated data is split into these sectors of the economy: agriculture, mining and quarrying, manufacturing, trade, transport and communication, community, social and other services, electricity and water, building, mortgage, construction and real estate, business services and finally personal loans and households' loans. The quarterly data on sectoral lending of commercial banks covers period from 2011Q3 to 2016Q4. This period captures when a new monetary policy framework became operational and the Central Bank tightened policy to control the high inflation at the time. The analysis will focus on all the sectors of the economy that borrowed from the banks. Although heterogeneity exists between banks and sectors, we cannot distinguish between old and new loans. We also expect bank loans to exhibit persistent as loans usually involved new and old borrowing through restructuring of the loan payments, additional new borrowing due to increased credit limits and overdrafts.

The dependent variable is computed as a ratio of the total loans offered by each bank to a sector hence, the dependent variable captures balance sheet channel rather than the banking lending channel. Banks lent on average about 24 per cent of their loan portfolio to the building, mortgage, construction and real sector, with one bank lending up to 72 per cent of their loan book. Banks also on average lent about 23 per cent to the trade sector with one bank lending about 71 per cent of its loan book. The least lent sector was the mining and quarrying sector reporting an average of 1 per cent of banks' loans (see Table 2.2). The quarterly data on banks' balance sheet is used to study the credit channel and we consider bank's attributes that measure the liquidity, the assets, capitalisation and profitability. A bank's liquidity is defined as a ratio of liquid asset to total assets, while capital is defined as the ratio of total capital to total assets. Profitability is defined as the ratio of net profit to total assets and finally the log of total assets presents the assets of that bank. The robustness of our results is tested by splitting the data into the fourth and second quartiles according to the level of bank capitalisation. As the banking sector is highly concentrated, with few banks owning the largest proportion of the sector's total assets. In this specification, we also introduce a non-performing loans variable, defined as a ratio of non-performing loans to total bank credit as a control. The central bank's bank rate (CBR) is used as a policy rate and used as measure of monetary policy stance. Quarterly GDP data is used to measure economic activity. Inflation is measured by core inflation, a standard measure used by the Central Bank.

	Mean	Std.Deviation	Minimum	Maximum	Observations
Economics sectors					
Real Estate	0.24	0.14	0.00	0.72	475
Trade	0.23	0.18	0.00	0.71	475
Transport	0.07	0.06	0.00	0.44	474
Personal loans	0.11	0.11	0.00	0.45	433
Manufacturing	0.13	0.11	0.00	0.62	468
Commercial	0.06	0.09	0.00	0.93	475
Agriculture	0.08	0.07	0.00	0.30	475
Business	0.07	0.08	0.00	0.41	475
Mining	0.01	0.02	0.00	0.10	458
Bank attributes					
Capital	22.95	13.68	-17.71	94.66	502
Liquidity	35.45	15.97	11.37	104.32	502
Return on Assets	1.27	3.23	-20.95	8.08	501
Ln_Asset	8.54	0.59	6.98	9.66	502
Macroeconomic variables					
Core Inflation	7.07	5.37	1.90	22.40	525
Headline Inflation	7.26	6.11	1.90	24.10	525
Leading Indicator	1.53	1.02	0.16	3.59	525
Real Policy rate	7.31	2.66	-0.40	10.20	525
Policy rate	14.38	3.63	11.00	22.00	525

Source: Bank of Uganda.

Table 2.2: Summary Statistics for bank, sectoral and macro variables.

2.6 Methodology

2.6.1 Vector error correction model

In motivating this paper, we investigate the relationship between the policy rate and the various sectors of the economy using the monthly aggregated dataset. All the data is subjected to unit roots tests[2]. Results suggest that some non-stationary variables are present, leading us to implementing a VECM. The VECM model is presented as VAR(p) of a mixture of I(1) and I(0) variables and ignoring the constants and deterministic trends, the model is initially specified as follows:

$$X_t = \Phi_1 X_{t-1} + ... + \Phi_p X_{t-p} + \epsilon_t \tag{2.1}$$

Where X_t is a K-dimensional vector of observable variables, ϵ_t is a k-dimensional vector of reduced-form error terms. Without considering the deterministic terms we can subtract X_{t-1} on both sides of equation 1,and write it in form of an error correction representation.

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{p-1} \Phi_i^* \Delta X_{t-1} + \epsilon_t \tag{2.2}$$

Where $\Pi = -(I_k - \Phi_1 - ... - \Phi_p)$ and $\Phi_i^* = -(\Phi_{i+1} + ... + \Phi_p)$ and ΔX_t is first difference of X as shown in (2.2). We observe from (2.2), that X_{t-1} is the only nonstationary variable. Since the left-hand side of the equation is I(0), this implies that the term ΠX_{t-1} should be an I(0). If the matrix Φ is singular of rank r that means we can have r linearly independent cointegrating relationships. Suppose the matrix Φ is a $K \times K$ matrix of rank r, it can be expressed as a product of two $K \times r$ matrices of full column rank. If we defineα and β as two $K \times r$ matrices of rank r then $\Pi = \alpha\beta'$.

[2]See Table A.3 in the appendix.

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{p-1} \Phi_i^* \Delta X_{t-1} + \epsilon_t \tag{2.3}$$

The VECM is finally specified in (2.3), the error correction term $\alpha\beta' X_{t-1}$

In the estimation process the data is subjected to unit roots test, after which we determine the optimal lag length with a number of information criteria. We then investigate for the presence of a cointegrating rank and with these findings we then run the model. The validity of the model is tested from normality and auto-correlation. The error correction term, that measures the speed of adjustment from the equilibrium level, is observed with a negative expected sign as an indication of correction mechanism. For the short run dynamics, the Wald test is used to examine whether coefficients of a variable are jointly significant(see Table A.5).

2.6.2 Dynamic panel model

Although results from the VECM suggest that long run and short run relationships exists between the policy rate and the different sectoral lending, we are mindful of whether some of the banks' characteristics may account for these findings. In the preliminary analysis of dis-aggregated data is subjected to Fisher's panel unit roots tests and results show that all the variables are stationary[3]. To investigate this further, we employ panel data analysis techniques in the analysis of the problem. Identification of parameters using panel data methods can be made with less restrictive assumptions on exogeneity of covariates that other methods like time-series or cross-sectional techniques use. The method also controls for any potential biases that may result from endogeneity because of the inclusion of lagged dependent variables. The methodology used in this paper will closely follow Kandrac (2012). The sectoral share of loans advanced by each bank is computed and used as the dependent variable. The inclusion of bank-specific variables such as assets, capital and liquidity in the model specification is supported by credit channel literature. For instance, Kashyap and Stein (2000,1995) and Kishan and Opiela(2000) report that big banks are less responsive to changes in monetary policy. To account for these differences in the balance sheet channel these bank specific variables (BSV) are interacted with the policy variable (RCBR*BSV). Gross domestic product(GDP) and the consumer price index are used to measure the real economy. In addition, a real policy rate to measure the monetary policy stance is applied in the analysis of the problem. In the computation of real policy rate, core inflation is used as the measure of inflation. All the variables are then tested for presence of panel unit roots tests as loan data are known to exhibit persistent. In estimation, we note that developments in the banking sector have a potential to impact on monetary policy decisions, creating an endogeneity problem to mitigate this, we make use of the dynamic General Methods of Moments (GMM) panel methodology. The GMM methodology is also used to control for any likely correlation between bank-level fixed effects and their lagged dependent variables and loans are known to be sticky, Bernanke and Blinder

[3]Details of the Fisher's panel unit roots test are presented in Table A.4 in the appendix.

(1992b). The approach involves obtaining first differences of the equation to eliminate unobserved heterogeneity. In the estimation, we employ the Blundell and Bond (1998) estimator that incorporates an additional assumption to the standard Arellano-Bond estimator by imposing further restrictions on the dependent variable process. The Arellano-Bond estimator exhibits "substantial downward bias when the coefficient on the lagged dependent variable is close to unity, as then the dependent variable follows a near random walk and lagged levels correlate poorly with lagged differences, thus creating a weak instrument problem." It is assumed that the first differences of instrument variables are uncorrelated with the fixed effects and this helps to cater for more instruments hence, improve efficiency. This estimator can be used in situations where the models are weakly exogenous and have predetermined covariates. The dependent variable is defined as in (2.4), and the dynamic panel model is specified as in (2.5), below:

$$\Gamma_{i,j\ ,t} = \frac{total\ loans\ to\ sector_j\ at\ period_t}{total\ loans\ of\ bank_i\ at\ period_t} \tag{2.4}$$

$$\Gamma_{i,j\ ,t} = \sum_{s=1}^{k} \alpha_j \Gamma_{i,j\ ,t-s} + \begin{bmatrix} RCBR_t \end{bmatrix} \begin{bmatrix} \beta_j \\ \delta_j * (CAP),i,_{t-1} \\ \omega_j * (ROA)_{i,t-1} \\ \tau_j * (LIQ)_{i,t-1} \end{bmatrix} + \mu_i BSV_{i,t-1} + \chi GDP_t + \nu_i + \psi_j + \epsilon_{i,j\ ,t} \tag{2.5}$$

For I = 1,. . . ..,N banks, j= 1,. . . ..,K sectors, t is the time, RCBR is the real policy rate. GDP measures economic activity and BSV is a vector of bank specific variables:capital, liquidity, assets, profitability. In the equation bank attributes such as LIQ as the liquidity of a specific bank, CAP as the capital of a specific bank. ROA as return to assets, a measure of profitability of a specific bank.

Where ν_i represents the unobserved bank-level effects, ψ_j represents the unobserved sector-level effects and $\epsilon_{i,j\ ,t}$. The error term is assumed to be independent and identically distributed $X \sim \mathcal{N}(\mu, \sigma^2)$.

From the estimated results we are particularly interested in the sign of policy rate variable that can be either $\beta_j > 0$ or $\beta_j < 0$ in (2.5), indicating that banks can re-balance their loan portfolio from some sectors to other sectors. With restrictive monetary policy is operation, the real policy rate is assumed to increase as firms response by demanding more credit to met their fall in sales and a need to finance inventories and therefore a negative coefficient of real policy rate will be consistent with the balance sheet channel theory as noted in the previous section. A positive coefficient on the other hand, may indicate that the banks are willing to increase lending to some sectors a case for portfolio balancing and therefore this may not rule out the presence of a bank lending channel. According to the theory of the credit channel these differences are expected to show when monetary policy is tightened.

2.7 Results

2.7.1 VECM results

In this section I consider the VECM model results, shown in Table A.5 in the appendix. The results indicate a long-run relationship exists between the policy rate and the various sectors of the economy. The cointegrating equation, shows 10 per cent of the disequilibrium is corrected in one month, implying that it will take an average of a year for the policy rate to attain equilibrium. In the short-run all the sectors have a positive significant relationship with the policy rate with the exception of community services, where an insignificant value is observed. However, a joint test of coefficients using the Wald test shows that community, electricity and transport sectors are insignificant. This implies there is no granger causality between the policy rate and these sectors. Sectors that received a lower percentage of credit resulted to larger increases in the policy rate. The VECM model establishes that short and long-run relationships exist between the different sectoral lending variables and the policy rate. However, this finding does not address the research question; it provides support for further analysis. Using panel data analysis techniques to control for macroeconomic conditions and characteristics of lending banks, the research question is analysed in the next subsection.

2.7.2 Panel data results

In the estimation process, we test for the auto-correlation [4](StataCorp 2015). Also loans are known to have persistence and the Sargan test[5]is used to test for the overidentifying restrictions as instruments are used. Detailed results of other variables and the interactive terms used in

[4]Identically distributed idiosyncratic errors are serially correlated in first difference, rejecting the null hypothesis of no serial correlation in the first-differenced errors at order one does not imply that the model is misspecified.

[5]Under Variance-covariance matrix (VCE) vce(robust) assumption, the asymptotic distribution properties are unknown and the system GMM, can't compute the vce(robust) option

the analysis are presented in the appendix. For presentation purposes, results of policy are shown here. The policy rate coefficients and associated t-statistics are the main variables of interest in our analysis. In the baseline model in Table 2.3, I control for loan demand using the number of applications for loans. In six out of nine sectors, the demand variable coefficients are significant. However, the magnitude of these coefficients are insignificant in real terms. In the four out of nine sectors, namely real estate, transport, agriculture and trade sectors, a negative sign is associated to policy rate variable for each sector. This illustrates that an increase in the policy rate leads to a reduction in lending to these particular sectors if deemed less credit worthy. However, the real estate and the agriculture sectors show significant changes in the policy rate. With a unit increase in the policy rate decreases the proportion of lending to the real estate sector by 0.065 immediately, from an average share of lending of 0.25.

The share of agriculture sector lending decreases by 0.040 per cent after two quarters from an average of 7 per cent if the policy rate is increased by 100 basis points. However, all the increments across the different sectors are marginally significant. These observations may not necessary rule out the existence of balance sheet as the upward pressure on the lending ratio following a monetary policy shock might have dominated any changes in banks' loan portfolios preferences. As per banks' attributes, results show some statistically significant values for liquidity, assets and capital for some sectors. However, these values are likely to have marginal impact on the lending shares. For these values to affect the given sectors, the Central Bank will have to increase the policy rate by a bigger margin. The results show the real estate sector was sensitive to economic activity and on average this sector receives the highest amount of credit from the banks, with a percentage increase in policy rate leading to 0.004 decrease after two quarters on the average lending share of 0.24 this result will have a marginal effect on the lending ratio.

The robustness of our results is tested by considering quarterly banks' lending data, split according to the level of capitalisation. The data is split into two quartiles with the fourth quartile made up of the largest banks in Uganda and second quartile , banks with an average level of capitalisation. This is of particular interest as the banking sector in Uganda is highly concentrated with the largest three banks commanding the largest volume of loans. In addition, a non-performing loans variable is included in the specification of the model. As noted earlier, for presentation purposes we only show results of the policy rate as seen in Table 2.4, results shown are broadly in line with the baseline model. The coefficients of the non-performing loans are significant with the exception of the trade and community sectors.

In Table 2.5 results from the second quartile are shown, the expected sign is obtained in five out of the nine sectors with similar magnitudes to the coefficients of the baseline model. The expected sign attached to the policy rate is negative, indicating the balance sheet channel is operational. However, for their impact to affect the shares of lending, the Central Bank has to pursue an aggressive monetary tightening policy. Notably the real estate and agriculture are insignificant in this model specification. However, these sectors have the highest non-performing assets, this may suggest that banks with average level of capitalisation avoid lending to these two sectors. Is a risk transmission channel at work? These results from the second quartile show that it takes a longer time for monetary policy tightening to feed-through to the sectoral lending. These findings may reflect the role of bank capital is important in the transmission mechanism.

Under the tightened monetary policy regime, results show sectoral composition of bank credit changes. These changes are pronounced when the policy rate coefficient is negative. When the policy coefficient is positive we find some significant values. However, these changes are not big in real terms. This finding may indicate that banks are cautious when increasing credit limits in times of restricted monetary policy. Some bank attributes like liquidity, capital and size of the bank are statistically significant but these values have marginal effects on the amount lent and can have a bigger impact if large increases in the policy rate are implemented by the Central Bank.

In this chapter, we have focused on the balance sheet transmission as the main transmission system, but this approach fails to distinguish between the risk taking and balance sheet channels. The risk taking channel aims at capturing the impact of monetary policy stance on the perception of risk and its pricing. For instance, during a restrictive monetary policy phase financial intermediaries are sensitive to risk and therefore tend to reduce on the amount of credit advanced to firms, while the balance sheet channel takes into consideration the creditworthiness of the borrowers based on the collateral values and profitability. We have assumed that a negative coefficient associated to the policy rate is an indicator of a balance sheet channel as highlighted in the previous section. In order to differentiate these channels, we need data over a longer time horizon, an appropriate interest rate spread that can be used to capture risk. The data also limits us in that it only covers a period when the Central Bank changed its monetary policy framework and embarked on a monetary tightening regime. To identify the risk channel we may need both periods of tight and loose policy. In addition, we know that interest rates are quite sticky in developing countries and therefore this may hinder the transmission of monetary policy and the separation of the transmission channels.

Table 2.3: Quarterly sectoral lending in Uganda, by banks: Baseline model

	Trade	Manfacturing	Household	Transport	Agriculture	Estate	Electricity	Community	Mining
policy rate	0.00571	0.000176	-0.00297	-0.00429	0.0223	-0.0646**	-0.00412	0.00650	0.0428*
	(1.10)	(0.06)	(-1.46)	(-0.30)	(1.49)	(-2.81)	(-1.61)	(1.78)	(2.06)
L.policy rate	-0.0104*	0.00152	-0.00273	-0.00482	0.0211	-0.0224	0.00350*	-0.00689	-0.0239
	(-2.14)	(0.30)	(-1.05)	(-0.43)	(1.53)	(-0.96)	(2.08)	(-1.70)	(-1.55)
L2.policy rate	0.00277	-0.00334	-0.00564	-0.0272*	-0.0452***	0.0254	-0.00291	0.00564**	0.0132
	(0.68)	(-1.10)	(-1.41)	(-2.33)	(-3.83)	(1.06)	(-1.42)	(2.67)	(1.24)
L3.policy rate	-0.00205	0.000771	0.00499*		0.0389*				
	(-0.44)	(0.42)	(2.14)		(2.48)				
Arellano-Bond AR(1) (in prob)	0.0015	0.0009	0.0676	0.0011	0.0008	0.0176	0.0237	0.0968	0.2593
Arellano-Bond AR(2) (in prob)	0.9285	0.3835	0.1597	0.7863	0.2191	0.3967	0.1385	0.2241	0.2914
N	331	324	297	351	331	358	322	351	341

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.4: Test for robustness for the quarterly sectoral lending in Uganda, by banks in the highest quartiles of capital

	Trade	Estate	Transport	Household	Business	Community	Manufacturing	Agriculture	Mining
policy rate	0.0244***	0.122	-0.0316	0.00250	-0.788***	0.0162*	-0.0711*	-0.00181	0.000438
	(3.74)	(1.12)	(-1.71)	(0.35)	(-3.81)	(2.41)	(-2.04)	(-0.22)	(1.15)
L.policy rate	-0.0270***	0.302**	0.0399	-0.0138	0.364*	-0.0135**	0.00975	0.00947	0.000357
	(-5.23)	(2.71)	(1.22)	(-1.82)	(2.36)	(-2.60)	(0.31)	(1.05)	(0.87)
L2.policy rate	0.0137**	-0.313*	-0.0290	-0.0110*	0.495*	0.00116	0.0593***	-0.0118**	0.000948*
	(3.24)	(-2.28)	(-1.93)	(-2.11)	(2.16)	(0.50)	(4.11)	(-2.97)	(2.23)
L3.policy rate	0.00747	-0.131**	0.0262*	-0.0124	-0.0412			0.00379	-0.000383
	(1.44)	(-2.62)	(2.57)	(-1.91)	(-0.70)			(1.48)	(-0.88)
Arellano-Bond AR(1) (in prob)	0.0220	0.0300	0.0239	0.0549	0.0865	0.1112	0.1998	0.1052	0.2553
Arellano-Bond AR(2) (in prob)	0.1384	0.6982	0.1434	0.8184	0.3507	0.8567	0.7932	0.3754	0.0298
N	63	68	68	61	68	78	77	68	64

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.5: Test for robustness for the quarterly sectoral lending in Uganda, by banks in the second quartiles of capital

	Trade	Estate	Transport	Household	Manufacture	Community	Agriculture	Mining	Business
policy rate	-0.136**	-0.00213	-0.000694	0.0291	0.0829	0.0271	-0.00318	-0.000175	0.0421*
	(-3.22)	(-0.02)	(-0.27)	(1.12)	(1.03)	(1.73)	(-1.38)	(-0.37)	(2.04)
L.policy rate	0.128***	0.112	0.00208	-0.00887	-0.0326	-0.0325	-0.00187	0.0000168	-0.0277
	(3.70)	(1.30)	(0.88)	(-0.39)	(-0.61)	(-1.39)	(-0.92)	(0.03)	(-0.68)
L2.policy rate	-0.0113	-0.0609	-0.00338	-0.0213*	-0.0303	0.0585	-0.000379	-0.000317	-0.00999
	(-0.43)	(-1.09)	(-1.62)	(-2.34)	(-0.90)	(1.77)	(-0.17)	(-0.61)	(-0.26)
L3.policy rate	0.0274	-0.0211	0.00578*		-0.0124*	-0.0511*	-0.00276	-0.00237***	0.0166
	(1.66)	(-0.55)	(1.99)		(-2.16)	(-2.41)	(-1.33)	(-3.71)	(0.52)
Arellano-Bond AR(1) (in prob)	0.0377	0.0416	0.1300	0.0320	0.0338	0.1910	0.0070	0.8574	0.1406
Arellano-Bond AR(2) (in prob)	0.6088	0.3798	0.3071	0.3181	0.1485	0.2434	0.3453	0.3615	0.0209
N	90	90	92	82	88	90	91	86	

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

2.8 Conclusion

This chapter looks for evidence of monetary transmission mechanism with special reference to the balance sheet lending channel in Uganda following the introduction of new monetary policy framework. We find some evidence of a balance sheet transmission in Uganda, with the real estate and the agriculture sectors being disproportionately affected by restrictive monetary policy. These results are consistent with findings of Kandrac (2012). However, this has far reaching consequences in the Ugandan economy which is largely an agro-based economy and a reduction in credit to this sector will affect the overall growth in the country. Similarly, the real estate sector receives the largest proportion of credit advanced by banks and a big reduction in credit will surely affect growth in the country. This creates a policy dilemma for the Central Bank as growth enters into their objective function. These results also show that the level of bank capitalisation is important in determining what is lent by banks to the various sectors this finding is in line with what was reported by Kishan and Opiela (2000) for the US economy. As we observe, banks with average level of capitalisation fail to lend to the agricultural and real estate sectors. However, the common thread with these sectors is that they have the largest amount of non-performing loans. This raises the question: Are banks responding to the perceived risk associated with these sectors? If so, this brings another dimension to the debate and that is: Do we have a risk transmission channel at play? There is a need to distinguish between the balance sheet and risk taking transmission channels.

In the next chapter, we consider monetary policy efficacy by investigating whether a sector borrowing channel [6] is operational in Uganda. Bernanke and Blinder (1988) and Stein (1998) argue that for monetary policy efficacy, **credit market imperfections** are required at both bank and firm levels.

[6] This term is used in this chapter as opposed to the standard "firm borrowing channel" used in literature as data on firm level is restricted on grounds of confidentiality. We use data on a sector level and coin the phrase "sector borrowing channel"

Chapter 3

Does a sector borrowing channel exist in Uganda?

Abstract

In this chapter I investigate whether a sector borrowing channel exists in Uganda. Based on data from a credit register during the period between 2012Q1 and 2020Q2. I employed fixed effect models as described by Alfaro, García-Santana and Moral-Benito (2019), that allows for the use of bank and sector fixed effects. Results show that bank lending and sector borrowing channels are operational in Uganda in all currencies. As highlighted by Khwaja and Mian (2008), the existence of a sector borrowing channel in Uganda improves the efficacy of monetary policy. Although I have observed a sector borrowing channel is at the work in Uganda, the role of the banks is important. I note regional and non-DSIB banks' borrowers can offset the impact of credit supply shocks from loans in all currencies. However, local banks' borrowers are unable to offset shocks in both local and foreign currencies borrowing. This may indicate these sectors resort to borrowing from non-bank sources. In addition, all types of banks are more responsive to credit supply shocks, if loans are in foreign currencies this could affect the transmission of monetary policy. In terms of policy, we need to increase competition and efficiency of the banking sector.

3.1 Introduction

Implementation of monetary policy needs the Central Bank to control aggregate demand in the economy. In terms of monetary policy efficacy, the theoretical work of Bernanke and Blinder (1988), Holmstrom and Tirole (1997) and Stein (1998), argue that the transmission of financial shocks to the economy requires credit market imperfections at both bank and firm levels. An empirical study by Khwaja and Mian (2008) shows market frictions exist at bank and firm levels. The study highlights the importance of the "firm borrowing channel" in the bank lending transmission channel.

In Uganda, empirical work by Abuka, Alinda, Minoiu, Peydro and Presbitero (2019) and Opolot and Nampewo (2014) shows that a banking lending channel is operational. I differ from these papers by investigating for market frictions at bank and sector levels hence, whether bank lending and sector borrowing channels are functional in Uganda. In the estimation of the sector borrowing channel, I simultaneously disentangle the bank lending channel [1] from the sector borrowing channel [2]. This approach can be limited, if we lack data that links banks to different sectors over a period of time. I note an identification problem may arise from the separation of demand and supply shocks, as these shocks could be driven by similar factors. In this chapter, we estimate the bank lending and sector borrowing channels in Uganda, developing country characterised by a bank-dominated financial sector. I use dis-aggregated banks' sector lending data over a period of time.

Methodologically, I use bank-time-specific credit supply shocks identified by differences in credit growth between banks lending to the same sector, in the spirit of (Alfaro et al. 2019). This provides plausible exogenous shocks as sectors may react to a negative bank supply shock by borrowing from another bank(s) or consider resorting to a non-bank funding source. The

[1] The inability of banks to protect borrowing sectors from bank-specific liquidity shocks.

[2] The inability of borrowing sectors to smooth the impact of bank lending channel by borrowing from alternative funding sources.

latter may be limited in Uganda, given that the financial sector is not developed. As in Amiti and Weinstein (2018a) and Alfaro et al. (2019), my approach is based on a linear model that specifies the growth rate of loans from an individual bank to an individual sector as a function of bank-time and sector-time fixed effects.

Loan level data from the credit register compiled by Compuscan a credit reference bureau operating in Uganda is employed. The data contains loan level information for the banking sector offered on a quarterly basis across all sectors of the economy and covers the period between 2012Q1 and 2020Q2. Using the credit register data gives us the benefits of studying lending relationships between banks and sectors over time.

In validating the estimated bank-supply shocks the sample is split into Domestic Systematically Important Banks (DSIB) and non-Domestic Systematically Important Banks (non-DSIB). The data is further split into local, international and regional banks. With the increase of foreign currency lending in Uganda I explore whether banks and their borrowers behave differently in their lending and borrowing decisions. No significant differences are observed in the estimated supply shocks. Since no significant difference is observed in credit advanced by these banks we should expect no significant difference in the estimated bank-supply shocks and therefore our results are plausible.

This empirical work complements the above papers with results for Uganda. Evidence is presented from a different environment, namely a developing economy where financial market are relatively less developed and subject to substantial financial frictions. I find support for bank lending and sector borrowing channels. The result suggests a significant sector borrowing channel was at work in non-DSIB and regional banks based on local and foreign currency loans. During periods of liquidity shocks, results indicate DSIB and international banks borrowers respond by borrowing in foreign currency to offset the impact of the shocks. Also, based on foreign and all currencies lending, we note a non-significant sector borrowing channel for local banks' borrowers. This shows local banks' borrowers are unable to offset the impact of liquidity shocks and therefore resort to informal funding sources.

3.1.1 Related literature:

In the first strand of the literature we consider papers that study the bank lending channel as a transmission mechanism of shocks. Khwaja and Mian (2008) study how supply side bank liquidity shocks feed through to the economy in Pakistan using firm fixed effects models. They show a bank lending channel was operational in Pakistan. Observed is large firms are able to hedge against this shock by borrowing from other banks. This paper introduces the fixed effects method as a new approach of disentangling credit supply from demand. We follow a similar approach with fixed effect models used in the analysis. The fixed effect approach is used to estimate the unobservable covariance between credit shocks and credit demand shocks. However, this approach needs an instrument(s) that can be used to identify credit supply shocks. In this paper it was sanctions following a nuclear test by Pakistan. The method limits the scope of a study to a particular event hence, it can't be used over a long time horizon.

Abuka et al. (2019) show a bank lending channel is functional in Uganda using credit register data and regression techniques. The strong banking lending channel had big effects on real activity. Also noted, banks with lower capital transmitted monetary policy more. In addition, banks with higher liquidity responded to credit supply more. Although the paper, controls for credit demand on industry and district basis we differ in that we consider a sector breakdown. In another country-specific case, Opolot and Nampewo (2014) examine the relevance of bank lending channel of monetary policy in Uganda and employ a dynamic panel methodology in the analysis. The results indicate that a bank lending channel was operational in Uganda. They further show bank characteristics such as liquidity and capitalisation are vital in influencing the supply of loans. These findings are broadly in line with established literature. See Jiménez, Ongena, Peydró and Saurina (2012) and Kashyap and Stein (2000b).

Abuka et al. (2019) and Opolot and Nampewo (2014) confirm the presence of a bank lending channel in Uganda using micro data. However,these papers don't address the role of supply and demand shocks. So we take it to the next step by estimating the supply and demand shocks arising from banks' lending activity.

Another literature strand has focused on the real effects of banking lending shocks and these papers consider the problem. Amiti and Weinstein (2018a) investigate the impact of supply-side financial shocks on firms' investments using a new methodology of disentangling firm-borrowing shocks from bank supply shocks. Loan growth rates are expressed as a function of bank-time fixed effects and firm-time fixed effects. They show these effects were large. Based on a similar approach Alfaro et al. (2019) investigate the real effects of banking shocks and how they feed through to the economy based on Spanish data. The study shows credit supply shocks are sizable to real variables. Our paper closely follows this methodology and focuses on the firm borrowing channel. This approach resolves all the limitations highlighted in Khwaja and Mian (2008) and therefore is applicable to our data.

The paper is structured as follows: In Section 3.1, we provide an introduction and some related literature; Section 3.2 explores bank intermediation in Uganda, Section 3.3 ; looks at the data used in the paper; Section 3.4, considers the empirical analysis and finally Section 3.5 provides concluding remarks.

3.2 Bank intermediation in Uganda

3.2.1 Institutional background

Although Uganda's recent economic history has seen significant financial development, most indicators of financial development are still low by international standards. Similar to most low income countries, financial market depth in general, and the size of the banking system in particular, are smaller – in terms of domestic credit relative to GDP – and less open – in terms of de jure and de facto measures of financial integration – in Uganda than their counterparts in developed countries (Abuka et al., 2019; Bremus and Buch, 2015). Table 3.1 provides some relevant statistics for Uganda from the Bank of Uganda, Financial Stability Department.

	2012	2013	2014	2015	2016	2017	2018	2019	2020
(1) Private credit by financial sector to GDP(%)	10.38	11.93	11.14	11.56	11.42	11.20	11.23	11.67	11.86
(2) Private credit by banks to GDP(%)	9.98	11.45	10.71	11.08	10.89	10.69	10.69	10.96	11.20
(3) Bank dependence [(2)/(1)]	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.94	0.94
(4)Total loans to total deposits(%) [a]	74.96	73.42	70.48	73.14	70.67	64.41	65.18	64.71	61.16
(5)Total loans to total assets(%)	50.70	48.53	47.47	49.37	48.29	44.20	45.49	44.79	43.21
(6) Deposit dependence [(5)/(4)]	0.68	0.66	0.67	0.68	0.68	0.69	0.70	0.69	0.71
(7) Bank concentration (largest 3 banks, %)	45.19	42.41	40.51	39.05	40.78	42.84	40.79	41.53	42.63
(8) Bank concentration (largest 5 banks, %)	59.73	58.28	56.70	55.42	55.75	61.60	60.48	60.43	61.49

Source: Bank of Uganda, Financial Stability Department.

[a] All annual figures are computed as quarterly averages, figures in 2020 are an average of two quarters.

Table 3.1: Financial development and banking in Uganda (2012Q1-2020Q2)

Formal financial sector credit to the private sector has increased from 10.4 per cent of GDP in 2012 to 11.9 per cent of GDP in 2020. The overwhelming share of this is actually originated in the banking system, whose credit volume to the private sector expanded from 10.0 per cent to 11.2 Per cent of GDP over the same period. The Ugandan economy is thus characterised by significant *bank dependence*, with an average of 95 per cent of private sector credit coming from banks. The banking system itself is strongly dependent on deposit funding. Deposits as a share of GDP range between 14.6 per cent and 16.9 per cent (Global Financial Development Database, 2018), and they are by far the most important source of funding for bank assets. Indeed, *deposit dependence*, calculated as the fraction of bank deposits relative to assets, was at

68 per cent in 2012 and at 71 per cent in 2020. By contrast, the availability of wholesale funding is very limited; with a ratio of interbank borrowing to total deposits in the banking system at only 2 per cent in 2017 (Bank of Uganda Financial Stability Report, 2017), the interbank market is weak.

While Uganda still has a substantial informal financial sector, the formal banking sector is well-established and adequately capitalised,[3] though with a relatively small number of banks. It currently comprises 24 banks (mostly foreign- and privately-owned) and is characterized by a *high degree of concentration*. The market share (in terms of total assets) controlled by the three largest banks accounted for more about 40 per cent, and in 2019 the combined balance sheet of the five largest banks made up more than 60 per cent of the overall assets held in the banking system.

3.3 Data

Our subsequent analysis is based on data obtained from the Bank of Uganda, the national central bank which is also responsible for the supervision of the banking sector in Uganda. We use sector-level data on credit in the domestic banking system compiled by Compuscan, a credit reference bureau, for the Bank of Uganda. Compuscan maintains the credit register under the supervision of the Bank of Uganda. Covering the entire banking system in Uganda, it provides quarterly data on firm borrowing for the period from 2012Q1 to 2020Q2. Data used covers the period when the Credit Reference Bureau, produced clean and consistent run of data. Corporate borrowing is recorded either in local or foreign currencies, and foreign currency loans are converted to their local currency value using prevailing exchange rates obtained from Bank of Uganda databases.

[3] In 2017, the average tier one capital adequacy ratio and total capital adequacy ratio were 21.4 per cent and 23.6 per cent, respectively (Bank of Uganda Financial Stability Report, 2017).

The availability of data on firm level is restricted on grounds of confidentiality and regulatory constraints. The credit register data records the parties involved in each loan and thus allows for the classification of loans according to identifiable bank-sector pairs. We eliminate the two smallest banks from our data set as their lending is driven by special considerations and quantitatively insignificant. This leaves us with 23 banks, whose lending activity accounts for the bulk of private-sector lending in Uganda. Starting from the quarterly loan data, we consolidate the bank-sector level series into annual loan aggregates, computed as the total volume of credit provided by a lender (bank) to a particular sector over the quarter or year, respectively. At quarterly frequency, this produces a data set of 6,881 sectors borrowing in more than quarter. For the annual data, we end up with 1,535 bank-sector observations with credit relationships over more than one year.

We are interested in bank credit at a higher, sectoral level of aggregation. The loan series are broken down at the sector level in accordance with International Standard Industrial Classification (ISIC) codes used by the UBoS and the central bank.In detail, the eleven broad sectors are: Agriculture, Business, Electricity, Manufacturing, Mining, Household, Building, Social,Trade, Transport and Others. Table 3.2 provides a sectoral breakdown of bank loans in Uganda at quarterly frequency.

These variables are split into different banks' classification. In this chapter, banks referred to as "local", have their headquarters and most share ownership resident in Uganda. "Regional" banks are cross-border banks controlled and owned from other regional countries on the African continent and incorporated, registered and licensed in Uganda. International banks are multinational banks that have headquarters overseas([4].

In Table 3.2, Table 3.3 and Table 3.4, we compute quarter on quarter growth rates for a number of variables for the period 2012Q1-2020Q2. The period reflects when the credit reference bureau produced a clean and consistent dataset. Commonly used Financial Stability Indicators (FSIs)

[4]Details of banks' classification by origin are provide in Table B.1

are considered and these are: Capital is used to measure the level of capital the bank holds and is defined as the ratio of total capital to total assets. Asset is a variable used to measure the asset quality and is defined as the ratio of non-performing loans to total gross loans. The profit variable is used to reflect how profitable banks are and defined as the ratio of bank profit to its total assets. Liquidity is a variable used to capture how liquid the banks are and its defined as the ratio of liquid assets to total deposits. Banks' market risk (market) is captured as forex exposure to regulatory tier 1 capital.

	Observations	Average growth	Standard Deviation	Minimum	Maximum
Agriculture	668	2.89	93.92	-983.47	788.46
Building [a]	1571	4.25	81.27	-1377.44	1343.09
Business	634	2.99	48.66	-214.04	229.81
Electricity	277	7.13	183.32	-1239.04	1357.12
Household	197	2.60	18.11	-103.20	99.69
Manufacture	653	3.15	82.30	-1112.58	869.13
Mining	404	0.41	183.53	-1595.35	1225.75
Others	451	-7.81	188.03	-1114.00	1347.38
Social	639	4.69	79.27	-717.85	474.23
Trade	722	3.57	56.84	-728.46	813.15
Transport	666	1.66	70.01	-686.10	732.72
All Sectors	6882	2.67	101.33	-1595.35	1357.12

Source: Bank of Uganda.

[a] Building includes commercial and residential mortgages.
[b] Average quarterly credit growth statistics are reported as unweighted mean.

Table 3.2: Loan dynamics in Uganda (2012Q1-2020Q2) for both domestic and foreign currency loans.

	Observations	Mean	Standard Deviation	Minimum	Maximum
DSIBs					
Capital [a]	1460	20.50	12.15	7.81	71.63
Asset [b]	1460	6.09	3.44	0.00	21.51
Profit [c]	1460	1.23	2.06	-8.34	6.03
Liquidity [d]	1460	34.99	15.73	13.32	76.05
Market [e]	1460	-3.33	9.38	-25.74	17.42
Credit	1460	1.46	134.15	-1595.35	1357.12
Non-DSIBs					
Capital	5422	20.58	12.24	8.09	67.00
Asset	5422	6.00	3.48	0.00	23.92
Profit	5422	1.24	2.08	-7.86	7.39
Liquidity	5422	35.29	15.77	4.98	76.05
Market	5422	-3.31	9.21	-25.74	21.96
Credit	5422	3.00	90.50	-1124.15	1132.21
All Banks					
Capital	6882	20.56	12.22	7.81	71.63
Asset	6882	6.02	3.47	0.00	23.92
Profit	6882	1.24	2.08	-8.34	7.39
Liquidity	6882	35.22	15.76	4.98	76.05
Market	6882	-3.31	9.24	-25.74	21.96
Credit	6882	2.67	101.33	-1595.35	1357.12

Source: Bank of Uganda.

[a] Capital is defined as the ratio of total capital to total assets.
[b] Asset is defined as the ratio of non-performing loans to total gross loans.
[c] Profit is defined as Return on Assets.
[d] Liquidity is defined as the ratio of liquid assets to total deposits.
[e] Market is defined as forex exposure to regulatory tier 1 capital.

Table 3.3: Credit growth and Financial Stability Indicators of DSIBs and Non-DSIBs banks (2012Q1-2020Q2) for both domestic and foreign currency loans.

	Observations	Mean	Standard Deviation	Minimum	Maximum
Local Banks					
Capital	957	20.88	12.51	10.45	71.63
Asset	957	6.10	3.49	0.00	21.51
Profit	957	1.30	2.13	-7.86	6.03
Liquidity	957	35.07	15.62	15.75	76.05
Market	957	-3.44	9.18	-25.74	17.42
Credit	957	4.08	49.80	-421.10	585.00
International Banks					
Capital	1588	20.45	12.03	9.98	63.01
Asset	1588	6.03	3.44	0.00	16.15
Profit	1588	1.23	2.05	-3.33	6.46
Liquidity	1588	35.16	15.81	13.32	76.05
Market	1588	-3.37	9.36	-25.74	21.96
Credit	1588	3.03	125.52	-1377.44	1357.12
Regional Banks					
Capital	4337	20.53	12.22	7.81	63.01
Asset	4337	6.00	3.48	0.00	23.92
Profit	4337	1.23	2.08	-8.34	7.39
Liquidity	4337	35.28	15.78	4.98	76.05
Market	4337	-3.27	9.22	-25.74	20.65
Credit	4337	2.23	99.91	-1595.35	1132.21
All Banks					
Capital	6882	20.56	12.22	7.81	71.63
Asset	6882	6.02	3.47	0.00	23.92
Profit	6882	1.24	2.08	-8.34	7.39
Liquidity	6882	35.22	15.76	4.98	76.05
Market	6882	-3.31	9.24	-25.74	21.96
Credit	6882	2.67	101.33	-1595.35	1357.12

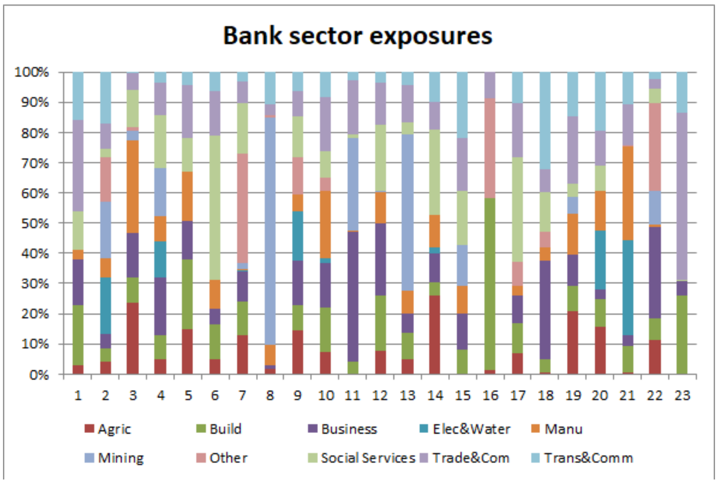
Source: Bank of Uganda.

[a] Average credit growth statistics reported as unweighted mean.

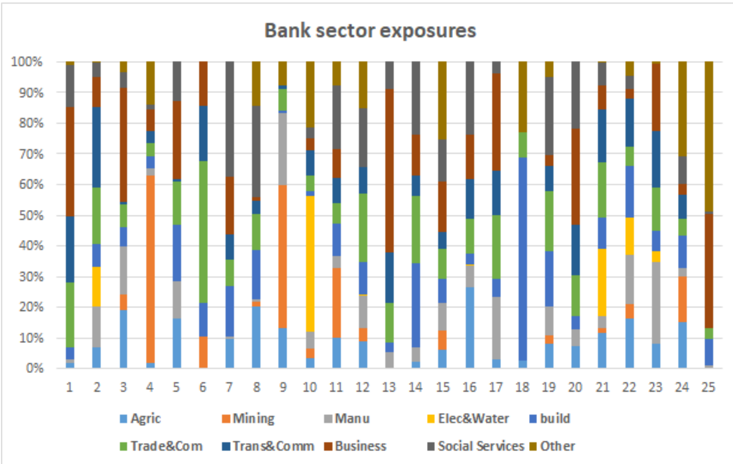
Table 3.4: Credit growth and Financial Stability Indicators by bank origin (2012Q1-2020Q2) for both domestic and foreign currency loans.

Exploiting the loan-level data, we are able to paint a detailed picture of banks' loan exposures and their change at business cycle frequency. Figure 3.1 presents two snapshots of the data in terms of the annual averages of outstanding loans by sector for each of the banks in our sample. Two observations are striking: First, there is substantial heterogeneity in sectoral loan exposures across banks. For example, in 2015 the share of real estate lending ranged from 0 per cent (bank 1) to 24 per cent (bank 22); similarly, the exposure to the manufacturing sector varied from 0 per cent (bank 1) to 25 per cent (bank 23). Second, this heterogeneity appears to be persistent. Although there are noticeable shifts in the composition of individual banks' loan books over time, there are evident patterns of specialisation. For each bank, the Spearman rank correlation between its sectoral exposures in 2015 and 2019 is positive and significant, and the correlation coefficient is given by 0.54. We take this as evidence of *relationship lending*, where expertise and relationship capital are built up within bank-sector pairs.

As a consequence, differences across banks in the relative share of loans extended to individual banks display some persistence. Moreover, in addition to being dependent on bank credit as a means of external finance, individual firms operating in a given industrial sector are likely to find themselves locked into their relationship with their existing lenders. There is thus only a limited substitutability across bank loans originated by different banks, and financial shocks affecting banks' lending capacity can be expected to have real effects on their borrowers. In the following section, we substantiate this claim on the basis of linked bank-sector data.



(a) 2019



(b) 2015

Figure 3.1: Private-sector bank lending in Uganda: annual average of outstanding loans by sector

3.4 Empirical findings

A key challenge for empirical work on banking is to isolate changes in loan supply from changes in loan demand. This leads Khwaja and Mian (2008) to argue that the assessment of how shocks to the banking system affect the real economy must simultaneously confront two separate channels: the *bank lending channel* and the *sector borrowing channel*. The bank lending channel rests on banks' inability to insulate the borrowing sector from bank-specific liquidity shocks, while the sector borrowing channel is due to sectors' inability to address bank lending shocks by substituting towards alternative sources of financing.

In this section, we examine the bank lending and sector borrowing channels in Uganda, following ideas in Amiti and Weinstein (2018a) and Alfaro et al. (2019). Our approach exploits linked bank-sector data so that the unit of observation is given by x_{ib}, that is, the volume of loans from bank b to sector i. Specifically, our identification of supply and demand shocks to the growth of bank credit exploits the fact that each bank lends to multiple sectors, and each sector borrows from multiple banks.

Estimating idiosyncratic shocks to bank credit supply.

Amiti and Weinstein (2018a) show that the bank-time and sector-time fixed effects estimated on the basis of (3.1) are identical to those obtained from a specification that also allows for bank-sector-time effects Z_{ibt}. The key insight is that one can always express the interaction term as $Z_{ibt} = \varsigma_{bt} + \delta_{it} + \zeta_{ibt}$, where ζ_{ibt} is an error term. It is therefore possible to define the bank and sector shocks such that they are invariant to the inclusion of the interaction term, and they can be consistently estimated from equation (3.1).

Consider the following decomposition of credit growth between bank b and sector i at time t,

$$\Delta \ln(x_{ibt}) = \varsigma_{bt} + \delta_{it} + \epsilon_{ibt}, \tag{3.1}$$

where x_{ibt} denotes the average of outstanding loans from bank b to sector i over period t; ς_{bt} is a bank-time fixed effect, and δ_{it} is a sector-time fixed effect. Our baseline specification aggregates the monthly Compuscan data at quarterly frequency, but we also report estimates for annual data. The fixed effects in (3.1) can be interpreted as supply and demand shocks, respectively. In particular, ς_{bt} captures idiosyncratic shocks to bank b which are identified through differences in credit growth across banks lending to the same sector: From observing a sector whose credit from bank b displays stronger growth than that from bank b', we conclude that bank b was subject to a more favourable supply shock than bank b'. The identification of the demand shocks δ_{it} follows a similar logic. Finally, ϵ_{ibt} captures other shocks to the bank-sector relationship assumed to be orthogonal to the bank and sector effects.

Bank lending channel. We follow Alfaro et al. (2019) in estimating the magnitude of the bank lending channel. Our approach, implemented at the bank-sector level, amounts to estimating the following model,

$$\Delta \ln(x_{ibt}) = \beta^b \hat{\varsigma_{bt}} + \eta_{it} + \nu_{ibt}, \tag{3.2}$$

where $\hat{\varsigma_{bt}}$ is the bank-specific credit supply shock estimated in (3.1) and then normalised to have zero mean and unit variance. The sector-time fixed effect η_{it} controls for time-varying demand shocks, which is feasible due to banks' credit exposure to multiple sectors. The magnitude of the bank lending channel is then captured by parameter β^b; given the normalisation of $\hat{\varsigma_{bt}}$, the estimate can be interpreted in terms of the change in the gross rate of credit growth induced by a one-standard deviation bank-specific shock to credit supply.

Table 3.5, provides our estimates, contrasting effects at quarterly and annual frequency.

	quarterly bank-sector	annual bank-sector
credit supply shock	0.331***	0.532***
	(369.11)	(256.90)
obs	6881	1535
adj.R^2	0.169	0.245

Heteroskedasticity robust standard errors clustered at the bank level; t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3.5: Bank lending channel at loan level for both domestic and foreign currency loans

The first column examines the bank lending channel at the bank-sector level at quarterly frequency and identifies a positive and significant effect. Conditional on sector-time fixed effects, increased credit supply from a given bank implies higher credit growth for sector with a credit relationship to that bank. The magnitude of this effect is substantial: A one standard deviation credit supply shock gives rise to 0.33 percentage points in credit growth; this is relative to an average quarterly growth rate of credit of 2.67 percent. On annual basis a one standard deviation credit supply shock leads to 0.53 percentage points in credit growth; this is relative to an average annual growth rate of credit of 8.08 percent.

We conclude that the bank lending channel has potentially important effects at all considered levels of aggregation across time and sectors. Notice, however, in comparison to the estimates at quarterly frequency, the annual effects are slightly higher. This points to the fact that borrowers are able to partially offset the effect credit supply shocks over time. Indeed, borrowing firms may still be able to insulate themselves from idiosyncratic bank credit supply shocks by resorting to credit from alternative sources, and in particular from other banks.

Sector borrowing channel. In order to examine the question to what extent a negative bank lending shock actually translates into a reduction of available credit for borrowers, we use the idiosyncratic credit supply shocks $\hat{\varsigma}_{bt}$ identified in (3.1) to construct a measure of credit availability at sector level. Specifically, we again start from the normalised version of $\hat{\varsigma}_{bt}$ and compute the credit supply shock facing a particular sector as the weighted average of the idiosyncratic supply shocks across the banks with an existing credit relationship to the sector,

$$\bar{\varsigma}_{it} = \sum_b \frac{x_{ibt-1}}{\sum_b x_{ibt-1}} \hat{\varsigma}_{bt}. \tag{3.3}$$

Next, we regress sectors' credit growth on the constructed credit supply measure and the idiosyncratic demand shocks $\hat{\delta}_{it}$ (again normalised to have zero mean and unit variance) from (3.1),

$$\Delta \ln(x_{it}) = \beta^i \bar{\varsigma}_{it} + \gamma \hat{\delta}_{it} + u_{it}. \tag{3.4}$$

Similar to the bank lending channel estimated in (3.2), the magnitude of the sector borrowing channel is reflected in parameter β^i.

Table 3.6, provides our estimates, contrasting effects at quarterly and annual frequency.

	quarterly bank-sector	annual bank-sector
credit supply shock	1.090***	1.583***
	(7.67)	(6.09)
obs	5919	1361
adj.R^2	0.069	0.073

Heteroskedasticity robust standard errors clustered at the bank level;
t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3.6: Sector borrowing channel for both domestic and foreign currency loans

Based on quarterly data, the second column examines the borrowing channel at the bank-sector level. Our estimate implies that, controlling for credit demand, a one-standard deviation shock in the credit supply available to a given sector leads to an increase of the sector's bank credit by 1.09 percentage points. Notice, however, that the effect is bigger in magnitude than the corresponding estimate for the bank lending channel ($\beta^i = 1.09$ versus $\beta^b = 0.33$). This increase indicates that sectors have a higher response to the shock hence, a stronger transmission mechanism is operational at the sector level.

Revisiting the credit dynamics induced by credit supply shocks at annual frequency, column two, in Table 3.6, report borrowing channel estimates are statistically significant at the bank-sector level. This suggests that a stronger transmission takes places over a longer horizon. Comparing this estimate to its counterpart from Table 3.5, we observe higher values at the sector level of bank-specific shocks to credit supply. This implies a higher pass-through of idiosyncratic supply shocks to observed credit growth on both quarterly and annual frequencies. Our estimated effects for the sector borrowing channel are smaller than those obtained by Alfaro et al. (2019) for Spanish data. One underlying reason is that our identified bank credit supply shocks ς_{bt} display a very low volatility so that a one-standard deviation shock corresponds to a smaller absolute change in credit supply. This result suggests that over time sectors are able to adjust to the effects of a credit supply shocks.

In testing the validity of our credit supply shock estimates, we split the sample into DSIB and (non-DSIB). These DSIBs banks account for 50.8 percent of the banking sector total assets as reported by Bank of Uganda, Financial Stability Report, June 2019. We assume these institutions(DSIBs) are well capitalised and highly profitable and are resilient to shocks. Firstly, we test for whether the average realised supply shock is different for DSIBs versus non-DSIBs banks.

$$\Delta \ln(x_{ibt}) = \beta^b \hat{\varsigma_{bt}} + \eta_{it} + \nu_{ibt}, \tag{3.5}$$

Where b is bank classification for DSIB or non-DSIB banks. Note:each bank classification is run separately.

We estimate the (3.5) and the results are shown in Table 3.7. We observe positive and significant effects across the banks, conditional on sector fixed effects. Both DSIBs and Non-DSIBs banks recorded a similar growth in credit at bank-sector level during the period of the study. In the second column of Table 3.7, the coefficient shows a one standard deviation in credit supply shock to non-DSIBs banks leads to 0.33 percentage point increase in credit growth from these banks to sectors. These results are similar in magnitude to our estimated credit supply shocks in the baseline model. DSIBs and non-DSIBs are all well capitalised banks see table 3, we should expect a smaller response to the shocks. In their papers, Abuka et al. (2019) and Jiménez et al. (2012), observe that well capitalised banks are less sensitive to monetary policy shocks and this result is in line with these earlier findings.

Secondly, we consider if the average effect of the sector-specific shocks differs for DSIB versus non-DSIB banks by estimating (3.6).

$$\Delta \ln(x_{it}) = \beta^i \bar{\varsigma_{it}} + \gamma \hat{\delta_{it}} + u_{it}. \tag{3.6}$$

The above equation is run, conditioned on either the bank classification is DSIB or non-DSIB banks. Note:each bank classification is run separately.

Results of (3.6) are shown in Table 3.8, and show sector-specific shocks affect non-DSIBs banks' borrowers in a positive and statistically significant way. In terms of size, a one standard deviation credit supply shock to non-DSIB banks generates 1.05 percentage points increase in credit growth from non-DSIB banks to sectors. These borrowers face idiosyncratic supply shocks to observed credit growth, and therefore can find alternative funding from other banks following credit supply shock. In column one in table 3.8, shows credit shocks to DSIB banks borrowers are insignificant implying these borrowers are non-responsive to credit supply shocks. The inability of sectors banking with DSIB banks to adjust may suggest establishing a new banking relationships is costly as such is a financial market constraint. Or this result may speak to the credit quality of these borrowers hence, these lenders can still provide the needed funding.

	DSIB	Non-DSIB
credit supply shock	0.332***	0.331***
	(80.50)	(389.82)
obs	1460	5421
adj.R^2	0.153	0.182

Heteroskedasticity robust standard errors clustered at the bank level;
t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3.7: Banks' supply shocks on credit for both domestic and foreign currency loans

	DSIBs	Non-DSIBs
Supply shocks	1.359	1.053***
	(1.41)	(6.78)
obs	1284	4635
adj.R^2	0.100	0.054

Heteroskedasticity robust standard errors clustered at the bank level;
t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3.8: Supply shocks for DSIB and non-DSIB banks borrowers for both domestic and foreign currency loans

Measuring the impact of financial frictions among banks is important in a developing country as financial constraints are likely to be more pronounced. Debate in policy circles is that effects of cross-border banking vary a lot across countries and time periods and may largely depend on the regulatory framework, market structure and financial infrastructure as observed by Beck (2014). I test whether the origin of a bank plays part in its resilience to shocks, these institutions are broken down into international, regional and local (domestic) banks. In Table

3.9, I observe positive and significant effects across the banks, conditional on sector fixed effects. In the first column of Table 3.9, the coefficient shows that a one standard deviation in credit supply shock to local banks leads to 0.33 percentage point increase in credit growth from these banks to sectors. Similarly, as seen in the second, a one standard deviation in credit supply shock generates a 0.33 percentage point increase in credit growth from international banks to the sectors. However, we note that there is no significant differences in the way banks react to supply shocks across the banks' classification.

In Table 3.10 column one, no significant sector specific shocks are observed. This shows sectors banking with local banks are not in position to offset the impact of credit shock by borrowing from other banks. In Table 3.10 column two, no significant sector specific shocks are observed. This implies sectors borrowing from these international banks can not offset the supply shocks. The inability of sectors banking with local or international banks to adjust may suggest establishing a new banking relationships is costly and such is a financial market constraint. This result may speak to the credit quality of these borrowers hence, these lenders can still provide the needed funding. Is this a case of cream-skimming of the best borrowers by international banks as noted by Pelletier (2018)? In Table 3.10 in the third column we observe sectors banking with regional banks when subject to credit supply shocks; a one standard shock gives rise to 1.03 percentage points increase in credit supply. The ability of sectors banking with regional banks to adjust may suggest establishing a new banking relationships is not costly to these borrowers.

	(1) Local banks	(2) International banks	(3) Regional banks
credit supply shock	0.326**	0.334***	0.331***
	(26.71)	(92.28)	(512.92)
observations	957	1588	4336

Heteroskedasticity robust standard errors clustered at the bank level;
t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3.9: Credit supply shocks based on both domestic and foreign currency loans by bank origin.

	(1) Local banks	(2) International banks	(3) Regional banks
sector supply shocks	1.337	1.599	1.031***
	(1.35)	(1.87)	(5.95)
observations	828	1375	3716

Heteroskedasticity robust standard errors clustered at the bank level;
t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3.10: Sector-specific supply shocks on both domestic and foreign currency loans by bank origin.

Mathieu, Pani, Chen and Maino (2019) advance two main drivers of increased cross-border banking as search for yield and the need to diversify. In this paper, in line with search for yield goal, they note “banking groups were more reluctant to expand across borders when exchange rate risk made the associated gains more uncertain”. In Uganda, increased lending in foreign currencies has been previous observed and according to the Financial Stability report by Bank of Uganda June 2018, over the last four years the ratio of foreign currency loans to total loans was about 42.9 per cent. With this in mind we next investigate whether banks and their borrowers behave differently if loans are advanced in foreign currencies. In Table 3.11, we observe positive and significant effects across all banks, conditional on sector fixed effects. In the first column of Table 3.11, the coefficient shows a one standard deviation in credit supply shock to all banks leads to 0.52 percentage point increase in credit growth from all banks to sectors. A similar coefficient value is observed for DSIB and non-DSIB banks and this suggests no significant difference between these banks and therefore these institutions react to the shocks in the same way. However, for local banks one standard deviation in credit supply shock to these banks leads to 0.45 percentage point increase in credit growth from local banks to sectors. This indicates the local banks’ lending in foreign currency is less responsive to liquidity shocks.

	All banks	DSIB	Non-DSIB	Local	International	Regional
Credit supply shock	0.520***	0.518***	0.520***	0.454**	0.522***	0.520***
Observations	6129	1327	4802	856	1415	3858
Adj. R squared	0.21	0.151	0.222	0.091	0.24	0.214

Source: Bank of Uganda.

Table 3.11: Bank lending channel based on foreign currency lending

In Table 3.12 column 4, no significant sector specific shocks are observed. This implies sectors borrowing from these local banks cannot offset the supply shocks. The inability of sectors banking with local banks to adjust may suggest establishing a new banking relationships is costly and as such is a financial market constraint. Since we observed that sectors banking with local banks are unable to offset banking lending shocks in both local and foreign currency, see Table 3.10 column 1, which may indicate that these firms resort to borrowing outside the formal banking system. In a comparison of results from Table 3.10 and Table 3.12, we fail to observe a sector borrowing channel when all currencies are consolidated (see Table 3.10 column 2, for international banks' borrowers but a significant and positive value is noted in table 3.12 column 5. This shows international banks' borrowers switch to foreign currency borrowing in times of shocks and are in position to offset these shocks. Similarly we observe DSIBs banks' borrowers have no significant sector borrowing channel in all currencies loans (see Table 3.8 column 1), and significant value in Table 3.12 column 2 for foreign currencies loans. This indicates DSIBs banks' borrowers switch to foreign currency borrowing in times of shocks and are in position to offset these shocks.

	All banks	DSIBs	Non-DSIBs	Local	International	Regional
Credit supply shock	0.910**	1.854**	0.879**	0.991	1.327***	0.764*
Observations	5190	1148	4042	724	1204	3262
Adj. R squared	0.071	0.055	0.077	0.008	0.108	0.072

Source: Bank of Uganda.

Table 3.12: Sector borrowing channel based on foreign currency lending.

3.5 Conclusion

In this chapter, I investigate whether a sector borrowing channel exists in Uganda. Results show that bank lending and sector borrowing channels are operational in Uganda in all currencies. As highlighted by Khwaja and Mian (2008), the existence of a sector borrowing channel in Uganda improves on efficacy of monetary policy. Although we have observed a sector borrowing channel is at the work in Uganda, the role of the banks is important. We note regional and non-DSIB banks' borrowers are sensitive to the impact of credit supply shocks from both local and foreign currency loans. However, local banks' borrowers are unable to offset shocks in local and foreign currency borrowing. This suggests these sectors resort to borrowing from non-bank sources. In addition, banks are more responsive to credit supply shocks, when loans are in foreign currencies. This could affect the transmission of monetary policy.

On the other hand, domestic banks' borrowers cannot offset the impact of the shocks. Is this a case of cream-skimming of the best customers by foreign and regional banks as observed by Pelletier (2018)? Or a case where these organisations have superior monitoring and screening processes? As a policy response, we need to increase competition and efficiency in the banking sector. In the second chapter, I considered monetary policy efficacy and findings show banks' foreign currency lending is important in the transmission of shocks. However, with increased foreign currency lending the Central Bank has to intervene to stem wide volatility in the foreign exchange market and maintain a monetary policy stance. This leads us to the third chapter, where I investigate sterilised foreign currency (FX) interventions and its impact on domestic credit in Uganda.

Chapter 4

Sterilised FX Interventions and its Impact on Domestic credit in Uganda.

Abstract

We study the impact of sterilised FX intervention on credit growth in Uganda, in a banking environment characterised by capital and leverage constraints. Using Local Linear Projection (LLP) methodology as proposed by Jorda (2005) to analyse the impact of daily FX intervention on domestic credit and the transmission channels at work. We find sterilised FX interventions dampen credit growth for a period of about six months and it recovers thereafter. Evidence of a crowding-out channel is observed however, a exchange rate transmission channel is insignificant.These results support a case for the use of FX interventions as a financial stability instrument. However, this may need further investigation as there is a need to balance this tool with other macro-economic policies.

4.1 Introduction

Foreign currency(FX) intervention continues to play an important role in Uganda, with the Central Bank purchasing United States Dollar (USD) 470.7m in 2017/18 fiscal year[1] an equivalent of about 15 per cent of the country's foreign reserves. Although, evidence in support of regular intervention in foreign market is still scanty, as observed by Cespedes, Chang and Velasco (2017). The Bank, uses this measure to manage exchange rate volatility, manage monetary policy stance and for foreign reserves accumulation. The banking sector is at the heart of these transactions. The financial sector is dominated by banks that contribute an average of 96 per cent of private sector credit. Understanding the way these financial intermediaries operate as they extend domestic credit under risk and exchange rate constraints is important in a developing economy. Also considered, is the transmission mechanisms at work.

The Ugandan government, liberalised markets, the capital account and introduced flexible exchange rate mechanism as part of the structural adjustment process that was carried by the International Monetary Fund (IMF) and the World Bank. Also at the height of these reforms, the Ugandan government became a big beneficiary of official aid. The Ugandan shilling was subject to appreciation pressures on the back of these developments. As a policy response, the government sold foreign currency to the Central Bank in exchange for domestic currency. These actions led to the accumulation of foreign reserves by the central bank. Liberalisation of markets also led to the increased volatility of the exchange rate and increased the government's foreign exchange needs. Driven by the need to build up reserves while managing the increased domestic currency liquidity, the Central Bank has carried out FX and sterilised FX interventions. The Central Bank sold government securities to the market to managed Increased liquidity in the financial system. However, FX interventions can cause distortions to banking sector operations in developing countries that are characterised by a lack of deep financial markets. Reserve build-up activities can have opportunity cost in terms of interest differential between return on

[1] Bank of Uganda annual report 2017/18.

reserves and interest cost of external debt, as observed by Rodrik (2006).

The role of exchange rate in central banks' policy and macro models has tended to be downplayed; it is argued that exchange rate only becomes a problem when it affects inflation and output. Supported by the notion, sterilised foreign exchange interventions, which do not affect money supply have little impact on the exchange rate. The traditional thinking of international bodies like the IMF is to counsel that in times of large capital inflows countries should use prudent fiscal policy and exchange rate flexibility as policy responses. Diverting from this advice, emerging economies have used multidimensional tools, namely: macro-prudential policies, capital controls and FX intervention as a way to mitigate the effects of large capital inflows. Ghosh, Ostry and Qureshi (2017) report that central banks in many emerging market economies have used FX interventions as policy instruments in periods of rapid domestic credit growth as a result of increased capital inflows.

Theoretical studies on the impact of FX interventions on exchange rates, have suggested its effects are transmitted through signalling and portfolio balance channels. Through the signalling channel, FX interventions affect the exchange rate by providing information on the central bank's monetary policy stance. However, it is argued the signalling channel transmits information and therefore it is not an independent policy instrument as observed by Adler, Lisack and Mano (2015). The portfolio balance theory as advocated by the likes of Kumhof (2010) and Gabaix and Maggiori (2015) report, FX interventions affect exchange rates as domestic and foreign assets are considered imperfect substitutes. The relative supply of domestic assets increases, increasing the risk premium and creating depreciation pressures on the exchange rates.

Earlier empirical studies on the effects of FX intervention on the exchange rate are centred on developed economies. Studies find little evidence to support the use of FX interventions on exchange rate management. However, when major central banks jointly used FX interventions, the tool was effective as reported by Sarno and Taylor (2001). In emerging markets, studies show FX interventions impact on the level and volatility of the exchange rate as observed by Menkhoff (2013).

Hofmann, song Shin and Villamizar-Villegas (2019) report that sterilised foreign currency (FX) intervention also works through two separate channels:

1. The risk-taking channel of the exchange rate which leans against bank lending capacity due to effects of currency appreciation. Hofmann, Shim and Shin (2017) argue that with a currency mismatch, an appreciation of the shilling improves the balance sheet position of a USD borrower as their liabilities decreases relative to assets. An improved balance sheet position of a borrower encourages the banks to extend credit to the borrower. On the other hand, if the shilling depreciates against the USD it tends to tighten the financial conditions in the economy. Less creditworthy borrowers are credit constrained on the back of weakened balance sheets. Under this channel, credit risk premium is determined by the spot exchange rate and therefore it becomes a risk measure. Bruno and Shin (2015) also suggests banks that face risk constraints are affected by currency appreciation as tail-risk associated with loans is reduced, leading to increased credit supply. These authors consider this a risk-taking channel of the exchange rate.

2. Central banks often offset FX interventions by selling securities to banks, a way of reducing the increased liquidity created by the initial transactions. Increased holdings of OMO instruments or government securities by banks, reduces private sector lending hence, the "crowding out" channel. Through this channel, large public sector borrowing from the banking system takes place, reducing private sector credit. Although, it can be profitable for the lending banks, it hinders financial sector deepening as more resources are allocated to the public sector rather than the private sector that is often seen as an efficient resource user. Cespedes et al. (2017) observes that under a sterilised intervention, when a

government uses tradable foreign reserves to purchase nontradables it is equivalent to the government lending the tradable, and its effects feeds through to financial constraints. Cook and Yetman (2012) report findings from Asian emerging markets that show an increase in reserves accumulation leads to a significantly lower credit growth and attributed it to crowding-out effects.

The net impact of sterilisation FX intervention by the Central Bank can be quantified by the exchange rate and OMO transmission mechanisms. Our paper aims at investigating the impact of foreign exchange intervention on credit growth in Uganda and the transmission mechanisms through which this happens. At the heart of this paper is how banks advance credit in an environment where risk constraints interact with macro-financial indicators like the exchange rate. Diamond, Hu and Rajan (2018) report a link between exchange rates and credit developments and note FX intervention can moderate credit booms, creating a macroprudential tool.

The following hypotheses are empirically tested:

- The effects of sterilised FX intervention on credit growth. We expect increased purchases of foreign assets by banks is likely to reduce on domestic credit supply through the risk taking channel of currency appreciation, which drives investor risk taking and supply of credit. Hofmann et al. (2017) observe a depreciate of local currency is associated with tightening of financial conditions. As the financial health of borrowers deteriorates, banks extend credit to fewer creditworthy borrowers and therefore credit supply tightens.
- The effects of sterilised FX intervention on the exchange rate. We should expect that FX purchases will depreciate the domestic currency. In line with the portfolio balance theory, that suggests when domestic and foreign exchange rates are traded, the relative supply of domestic exchange rates increases hence, the expected depreciation pressures on the local currency.

- The impact of Central Bank's open market operations on domestic lending. We expect given banks' balance sheet constraints such as leverage and capital requirements, an increase in supply of OMO instruments by the Central Bank, as part of the FX sterilisation process will decrease on domestic credit supply. As banks exchange domestic currency for government securities, they lend more to the public sector as opposed to the private sector hence, the reduction in private sector credit.

In this chapter, we use a high-frequency(daily) FX intervention, OMO datasets from the Central Bank and a comprehensive credit register of banks' lending to the real economy. The high frequency and panel structure of the credit register is the empirical identification strategy employed as endogeneity issues that may a raise between FX decisions and exchange rates, (Adler et al. (2015)). With high frequency data the contemporaneous relationship between exchange rate and intervention decisions can be broken as intervention is done at a lower frequency in comparison to exchange rate movements. Additionally, this approach may mitigate effects of reverse causality that may existence between FX intervention decisions and market outcomes like the exchange rate as observed by Dominguez, Fatum and Vacek (2013) . However, since we intend to control for banks' balance sheet quantities and the available data is monthly, we assume that there is no contemporaneous relationship between banks' lending and FX decisions and rather banks look at the whole lending portfolio.

We find sterilised FX purchases negatively affect credit growth in Uganda. However, the decline is not persistent. The crowding-out channel is the main transmission mechanism through which effects of sterilised FX interventions feed through to domestic credit. The empirical exercise fails to find evidence of an exchange rate transmission mechanism operating in Uganda following a sterilised FX intervention shock. Our paper adds to the literature that links FX intervention and exchange rates in a banking sector facing capital and risk constraints in a developing country. FX intervention has a dampening effect on domestic credit hence, one can use this macro-prudential policy for financial stability purposes during periods of credit booms.

The chapter is structured as follows. In Section 4.2, we derive and explain the underlying theoretical model and its implication on domestic credit. In Section 4.3, data used in this paper is described. Section 4.4, the empirical methodology and results are explored. In the final Section 4.5, conclusions of the paper are presented.

4.2 Theoretical model

In a non technical explanation of Hofmann et al. (2019) model, banks lend to business (firms) or government. The private sector is lent in either domestic or foreign currencies[2]. Banks are capital and risk constrained. These banks lend to business for project investment that is subject to risks. Firms pay back the borrowed funds and this depends on the project's outcome. These outcomes are random and subject to risks. These risks can be diversified (idiosyncratic) or non-diversified (systematic). The borrower only pays back the loan if the value of project outcome is greater than the sum of loan repayment and valuation effects of exchange rate movements. The business health of firms improves as the local currency appreciates, as cash-flows of these businesses are in local currency (Ugandan shillings). With a currency appreciation, the likelihood of loan defaults decreases. Banks respond by lending more to the private sector as risk constraints preventing lending are less binding. The banks have to decide what proportion of their limited capital is allocated to loans and government bonds. The amount banks lend to the private sector is determined by a parameter and that factor is an increasing function of the exchange rate. Government borrowing depends on some leverage factor. If exchange rate appreciates (depreciates) more capital is allocated to loans (bonds). As more capital is allocated to bonds, private sector lending is decreased hence, the crowding out effect.

[2]According to Financial Stability report by Bank of Uganda June 2018, over the last four years the ratio of foreign currency loans to total loans is about 42.9 per cent.

The detailed model is based on a theory advanced by Bruno and Shin (2015) that links the banking sector and borrowers. The model assumes borrowers are risk-neutral and invest in projects. Each project uses one unit of labour and borrows one unit of fixed capital from banks. The loans are denoted in Ugandan shilling at time 0. The borrower is assumed to have an existing debt of one dollar that is subject to valuation effects of currency movements. The investment matures at time 1, giving raise to a project outcome. Loan repayment is due at time 1, when the project matures and the value of the loan is 1+r where r is the loan interest. The dollar value of the shilling at period 0 is denoted by Ψ , with a higher value implying a stronger shilling. The project outcome (realisation) V_1 is a random variable and follows the Merton(1974) model of credit risk as specified in the for-mentioned paper.

$$V_1 = exp\left\{1 - \frac{s^2}{2} + sZ_i\right\} \tag{4.1}$$

We define Z_i as a standard normal and s is a constant. A bank's loan book is exposed to credit risk as specified in Vasicek(2002) model.

$$Z_i = \sqrt{\rho}X + \sqrt{1-\rho}Y_i \tag{4.2}$$

Where X and Y_i are mutually independent standard normals and represent systematic and idiosyncratic risk factors facing borrower i respectively. The parameter ρ assigns a weight to the risk factor X and is bounded between zero and one. The borrower defaults when the value of project outcome V_1 is less than the sum of loan repayment given by $1+r$ and valuation effects of exchange rate movements $\frac{1}{\Psi}$. A bank can diversify away the idiosyncratic risk Y_i associated with each borrower and the systematic X risk cannot be diversified in project outcomes. Based on the risk-taking channel of the exchange rate, the implication of currency mismatch that may arise from a dollar currency borrower assumes that the balance sheet of the debtor improves, following a shilling appreciation against the dollar. The individual borrower default risk reduces leading to a reduction in bank's loan portfolio tail risk. As a result a bank facing a Value-at-Risk (VAR) constraint, responds by providing higher credit on a back of a smaller tail risk.

4.2.1 Bank capital allocation

Each bank has a loan and bond division, with its total capital split between these divisions and all the capital is in shillings. Total capital C_b for each bank is split between the two divisions. Capital allocated to the bond division is represented by K_b^B, while loan division K_b^L takes up the rest of the capital. This relationship is captured by the equation below:

$$C_b = K_b^B + K_b^L$$

Lending by the loan unit is constrained by VaR rule that states the probability of loan losses should not exceed the capital allocated to the unit by some constant probability $\alpha > 0$. The model suggests as the shilling appreciates, individual borrower's(idiosyncratic) risk reduces. With this, bank's loan portfolio tail risk reduces and a VaR constrained bank, increases its lending to the private sector.

From the balance sheet identity: Assets = liabilities plus Equity. If total lending W_b by bank b are assets(loans) for the bank, K_b^L is equity allocated to the loan division and L_b is the total non-equity funding amount and its associated funding rate is given by f. Then the balance identity can be expressed as follows:

$$W_b = L_b + K_b^L \tag{4.3}$$

However, we know that the debt ratio which is defined as the ratio of total liabilities to total assets and follows a standard normal as shown in lemma 1 and 2 in Hofmann et al. (2019). The standard normal Ω is defined by the probability of default and is a function of the exchange rate. The weight ρ assigned to the common factor of X and the VaR rule constraint. It can take on the value of 0 or 1 .

$$\frac{(1+f)L_b}{(1+r)W_b} = \Omega \tag{4.4}$$

From the above equation L_b can expressed as:

$$\frac{(1+r)W_b}{(1+f)}\Omega = L_b \tag{4.5}$$

Replacing the value of L_b in (4.3) the balance sheet identity can be written as:

$$K_b^L + \frac{(1+r)W_b}{(1+f)}\Omega = W_b \tag{4.6}$$

From (4.5) we obtain the value of K_b^L as:

$$K_b^L = (1 - \frac{(1+r)}{(1+f)}\Omega)W_b \tag{4.7}$$

Rearranging (4.7) we obtain the value of total lending W_b as:

$$\frac{K_b^L}{(1 - \frac{(1+r)}{(1+f)}\Omega)} = W_b \tag{4.8}$$

$$\frac{1}{(1 - \frac{(1+r)}{(1+f)}\Omega)} = \lambda \tag{4.9}$$

Then total lending W_b by bank b can be defined as in (4.10), where λ is an increasing function of Ψ, the dollar value of the shilling and is identical across all the banks.

$$W_b = \lambda K_b^L \tag{4.10}$$

With the above equation when the shilling appreciates the loan division of bank increases its leverage for a given level of capital. As the shilling appreciates, the loan portfolio's tail risk exposure decreases inducing banks to increase on their lending as the VAR constraint is eased.

The model assumes a bank's bond holdings is determined by constant leverage factor μ of the capital allocated to the bond division. Bond holding by a bank is given by:

$$B_b = \mu\big(C_b - K_b^L\big) \tag{4.11}$$

In aggregate terms i.e summing across all banks b, total loan supply by the banking sector is given by:

$$W = \lambda(\Psi)K^L \tag{4.12}$$

Similarly the aggregated bond holding by the sector, can be obtained from the expression below:

$$B = \mu\big(C - K^L\big) \tag{4.13}$$

Therefore in aggregate $C = K^L + K^B$ and this implies $K^L = C - K^B$. (4.12) can be rewritten as:

$$W = \lambda(\Psi)(C - K^B) \tag{4.14}$$

From (4.13) we can deduce that the amount of capital allocated to bonds by banking sector is given by $B/\mu = \big(C - K^L\big) = K^B$. If all the outstanding stock of bonds in shillings denoted by S is held by the banking sector. The Central Bank's sterilisation exercise is achieved when this market clearing condition $B = S$ holds. Using this expression in (4.14) we obtain the following expression:

$$W = \lambda(\Psi)(C - S/\mu) \tag{4.15}$$

Since $\lambda(\Psi)$ is an increasing function of Ψ it implies a shilling appreciation leads to an increase in lending to the private sector borrowers. In (4.15) we further observe that sterilised FX interventions that weaken(depreciate) the shilling will lower the amount of private sector loans supplied by banks. From (4.15), it further shows If the stock of outstanding bonds S increases, lending to the private sector falls hence, the "crowding out" effect on loans, assuming everything else is held constant. If banks hold more bonds, more capital is allocated to bond portfolio leading to a reduction in capital available to the loan portfolio. All this points to the trade-off between the two asset classes, additionally this shows through the sterilisation leg of FX intervention, private sector credit is negatively affected. If the outstanding stock of bonds increases and the shilling depreciates against the dollar at the same time, then the crowding-effects on private sector credit is amplified as leverage of the loan division decreases further.

4.3 Data

Table 4.1 provides summary statistics of daily loan data obtained from Compuscan, a credit reference bureau. It covers the period from January 2012 to December 2018, with a total of 15.2 million loan observations. Data used covers the period when the credit reference bureau produced a clean and consistent run of data. Loans are grouped according to these 12 sectors: agricultural, mining, manufacturing, trade, transport, electricity, building, community, business, government, personal and other sectors. From Table 4.1, we observe on average 25.4 million Uganda shillings was lent across all sectors; the lowest sector loan was 1 million shillings and the highest loan offered was 49.2 billion shillings across all the sector divisions. The government sector recorded the highest average borrowing of 163 million shillings and its highest sector borrowing stood at 1.5 billion shillings. The sector also borrowed the least number of loans of 197 transactions during the period of consideration. The highest number of 6.3 million transactions was received from the personal sector that incorporates personal, household and mortgage loans. The sector borrowed on average 15.3 million shillings and the highest lending of 31.3 billion was given to this sector. The agricultural sector the biggest employer [3] in the country received the second highest number of loan transactions, recording an average of 17.9 million shillings with the highest amount allocated to the sector at 32.5 billion shillings.

[3] According to Uganda National Household Survey produced by the Uganda Bureau of Statistics the Agriculture sector contributed to 64.6 percent of labour participation.

	Observations	Minimum	Mean	Median	75th Percentile	Maximum
Agriculture	1532483	1.01	17.9	4.2	10.0	32500
Mining	132923	1.01	14.0	4.0	6.6	20000
Manufacture	1373315	1.00	16.6	5.0	7.0	35000
Trade	706955	1.00	39.4	5.0	12.0	41100
Transport	86156	1.02	72.7	4.5	15.0	41100
Electricity	9902	1.05	76.8	2.0	5.3	16900
Building	708739	1.00	38.5	5.8	10.0	40000
Community	426222	1.00	20.3	4.0	7.0	7420
Business	1467850	1.00	41.8	5.1	9.1	49200
Government	197	1.50	163	50	162	1500
personal	6253614	1.00	15.3	6.1	9.7	31300
other	2538997	1.00	42.3	6.3	17.0	48000
Total	15200000	1.00	25.4	5.6	10.0	49200

Source: Compuscan and author's computations.

Table 4.1: Daily sectoral distribution of loan(millions) from the credit registry

In the analysis, monthly banks' balance sheet data of total assets, total liabilities and total capital are used. In addition, monthly macro financial variables such as inflation and net portfolio inflows are incorporated in the analysis. Data on daily VIX index is obtained from FRED database and used as a proxy for global market uncertainty. Additionally, data on daily lending activities by banks is sourced from Compuscan. Information on daily purchases and sales of foreign assets (currencies) is obtained from the Central Bank. Also data on Open Market Operations and foreign exchange rates are obtained from the central bank.

The Bank of Uganda uses FX intervention for its monetary policy operations, aimed at attaining low inflation under an inflation targeting frame and operates a flexible exchange rate regime and open capital account that presents challenges. The central bank uses the tool to manage excessive market volatility of the exchange rate and for liquidity management in the economy. These objectives are achieved by either selling or buying foreign assets (currency) as needed. FX interventions are used for building up the country's international reserves.[4]

In Table 4.2, on monthly average the Central Bank bought 3.92 million dollars for reserve accumulation with the highest monthly average purchased, reported at 10.53 million dollars of foreign reserves. Targeted interventions are used to address specific lumpy payments by corporations. The Central Bank sold on monthly average of 8.05 million dollars, with the largest monthly sale reported at 15.43 million dollars. In the reserves build-up process both pre-announced (non-discretionary) and discretionary approaches have been employed. FX interventions are used with discretionary intervention used to manage the exchange rate volatility and targeted intervention.

[4]The country's reserves should be in position to meet a three month import cover as stipulated by the IMF.

	Interventions	Mean	Median	St.Deviation	Minimum	Maximum
Targeted purchase(sale)	84	-8.05	-7.48	5.08	-15.43	11.28
Intervention purchase(sale)	27	-13.62	-17.50	19.35	-50.00	20.00
Reserve build-up	81	3.92	3.91	1.89	0.00	10.53
Net Fx Intervention	84	1.95	2.23	2.64	-7.96	8.01

Source: Bank of Uganda.

[a] All variables are measured in USD(millions).

Table 4.2: Monthly Interventions distributed by FX intervention method

We define net FX intervention as the sum of purchases of net of sales of foreign currency used for intervention, targeted interventions and reserve build-up purposes as the Central Bank often buys and sells foreign currencies on a given day. When the Central Bank purchases foreign currency it can exchange domestic currency for the foreign currency, resulting in an increase in domestic currency. To offset the increase in domestic currency the bank sells government securities and open market operations instruments (deposit auction and repurchase agreements) that decreases money supply in the economy. Data shows on a daily average, the Central Bank bought USD 3.23 million, with the highest purchase recorded as USD 53.70 million[5] while on monthly average, the Central Bank purchased 67.30 million dollars, with the highest purchase recorded at 187.20 million dollars. For instance we note, in January and March 2015, the Central Bank sold over 150 million dollars in these respective months as shown in figure 4.1. During this period, the shilling had depreciated by 14.4 per cent year on year (YoY) basis against the USD and by 9.3 per cent (YoY) on trade weighted basis in the respective months. The depreciation was due to a global strengthening of the USD, large current account deficit and high demand by the corporate sector[6]. On balance the largest component of FX interventions has been aimed at international reserves build up.

[5]Monthly average data on FX interventions are computed from daily intervention figures.

[6]Sourced from the Bank of Uganda's monetary policy reports for February 2015 and April 2015.

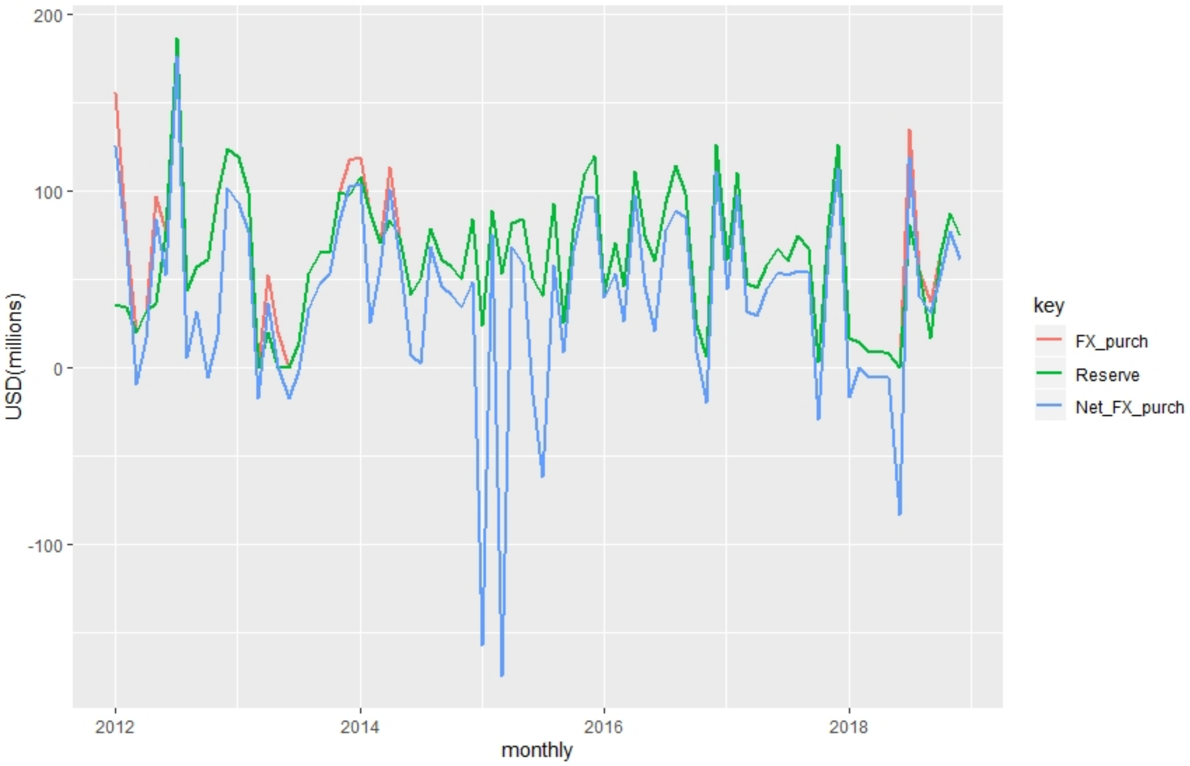


Figure 4.1: FX Intervention in Uganda(2012-2018) showing the different categories used.

In sterilisation of FX intervention, the Central Bank uses repurchase agreement (repos), reverse repos and deposit auction instruments for liquidity management and these form part of the OMO instruments. The liquidity management framework is based on a short-term liquidity forecasting exercise and short-term market intelligence as reported by Bacalu, Qureshi and Vandepeute (2015). It involves adjusting short-term (day-to-day) money supply to meet demand while meeting the Bank's operational money market rate (7-day inter-bank rate). The Bank's OMO injections averaged on daily(monthly) basis, on average the Central Bank issued UGX 257(307) billion worth of repos and reverse repos, with a maximum of UGX 1020(933) billion and the lowest daily repos issued at UGX 6.50(32.0) billion. In terms of auctioned deposits an average daily(monthly) of UGX 48.10(48.0) billion was auctioned, with the highest daily amount reported at UGX 688.0(502.0) billion (see Table 4.3 and Table 4.4).

The exchange rate(USD-UGX) peaked at 3890 shillings per dollar, averaging at 3096.5 shillings per dollar. The 7-day policy rate averaged 13.04 percent and the highest noted at 31.13 percent.The overnight policy rate averaged at 10.5 percent on a daily basis and the highest noted at 29.9 percent.

	Minimum	Mean	Median	95th Percentile	Maximum
Exchange rate(USD-UGX)	2311.70	3096.45	3285.00	3754.00	3890.00
Exchange rate(UGX-USD)	0.00025	0.00033	0.00030	0.00040	0.00043
Log of exchange(UGX-USD)	-8.27	-8.02	-8.10	-7.81	-7.75
Change in log of exchange rate(UGX-USD)	-0.04163	-0.00022	0.00	0.005581	0.061076
Policy rate(%)	0.09	11.04	10.05	19.93	30.42
Log of VIX index	0.00	1.17	1.15	1.35	1.61
Repos_reverse repos(UGX(B)	6.50	257.00	194.00	688.00	1020.00
Auction deposit(UGX(B))	0.00	48.10	33.00	162.00	688.00
Open market operations(UGX(B))	6.50	306.00	243.00	796.00	1260.00
FX sterilisation(USD(M))	0.00	3.23	2.00	11.20	53.70
Overnight policy rate(%)	0.00	10.46	9.55	19.33	29.86
7-day policy rate(%)	0.00	13.04	11.70	21.37	31.13

Source: Bank of Uganda.

Table 4.3: Daily statistics of macro and financial Indicators.

	Minimum	Mean	50th Percentile	Maximum
Repos (UGX) (B)	32.00	259.00	236.00	687.00
Auction Deposits (UGX) (B)	0.00	48.00	33.00	502.00
Open Market Operations (UGX) (B)	32.00	307.00	270.00	933.00
Overnight policy rate(%)	4.88	10.41	9.32	26.47
Seven day policy rate(%)	6.31	13.01	11.59	28.71
Credit growth	-0.99	2.43	0.00	199.00
Banks' assets (UGX) (B)	0.07	1.11	0.69	5.54
Banks' capital (UGX) (B)	0.01	0.18	0.11	0.90
Banks' liabilities (UGX) (B)	0.05	0.94	0.59	4.63
CBOE Volatility Index	10.13	15.23	14.30	24.95
Policy rate(%)	9.00	12.79	11.50	23.00
FX operations USD(M)[7]	-175.06	40.31	46.87	176.26
Exchange (UGX-USD)	0.00026	0.00033	0.00031	0.00043
Consumer price level	0.85	5.47	4.76	21.39
Net portfolio inflows (USD) (M)	-823.40	-339.19	-351.32	151.60
FX Intervention USD(M)	0.00	67.30	65.13	187.20
change in policy rate	-2.00	-0.15	0.00	1.50
Deviation from Inflation target	-4.15	0.47	-0.24	16.39
Log of volatility Index	2.32	2.70	2.66	3.22
Change in exchange rate (UGX-USD)	-0.06	-0.01	0.00	0.06

Source: Bank of Uganda.

Table 4.4: Monthly statistics of macro and financial Indicators.

[7] FX operations includes both the sale and purchase of forex, with a negative sign indicating a sale. FX intervention only captures purchase of forex through intervention, reserves build-up and target interventions.

4.4 Empirical specification

In the empirical analysis we investigate the impact of sterilised FX intervention on new credit issued by banks. In the next phase, we explore through which channels FX intervention affects new credit growth. We consider the impact of FX interventions on the exchange rate of the shilling against the USD. Finally we consider whether the "crowding out" channel operates, as the model suggests FX interventions impact on domestic credit through OMO.

The estimation approach is based on panel local linear projection (LLP) as pioneered by Jorda (2005). Under the LLP, the autoregressive coefficients can be estimated directly at each h-step-ahead, this involves regressing the dependent variable on its past as shown below:

$$\begin{aligned} y_{t+1} &= A_1^1 y_t + A_2^1 y_{t-1} + ... + A_p^1 y_{t-p} + \epsilon_{t+1}, \epsilon_{t+1} \sim MA(1) \\ y_{t+2} &= A_1^2 y_t + A_2^2 y_{t-1} + ... + A_p^2 y_{t-p} + \epsilon_{t+2}, \epsilon_{t+2} \sim MA(2) \\ y_{t+H} &= A_1^H y_t + A_2^H y_{t-1} + ... + A_p^H y_{t-p} + \epsilon_{t+H}, \epsilon_{t+H} \sim MA(H) \end{aligned} \tag{4.16}$$

Jorda (2005) shows that after estimating the $K \times K$ autogressive coefficients A_1^h, $h = 1, ..., H$ this is equivalent to estimating impulse response functions without re-writing the equations in the form of the Wold representation theorem. Errors obtained from the above exercise are vector moving average (VMA) processes of order h. The author highlights a need to estimate a variance-covariance matrix using a heteroskedasticity and autocorrelation consistent estimator (HAC) as defined by Newey and West (1987). As a result of the direct estimation used in the LLP method the author reports that the approach is more robust to model misspecification in comparison to VAR iterated procedures that are functions of the horizon.

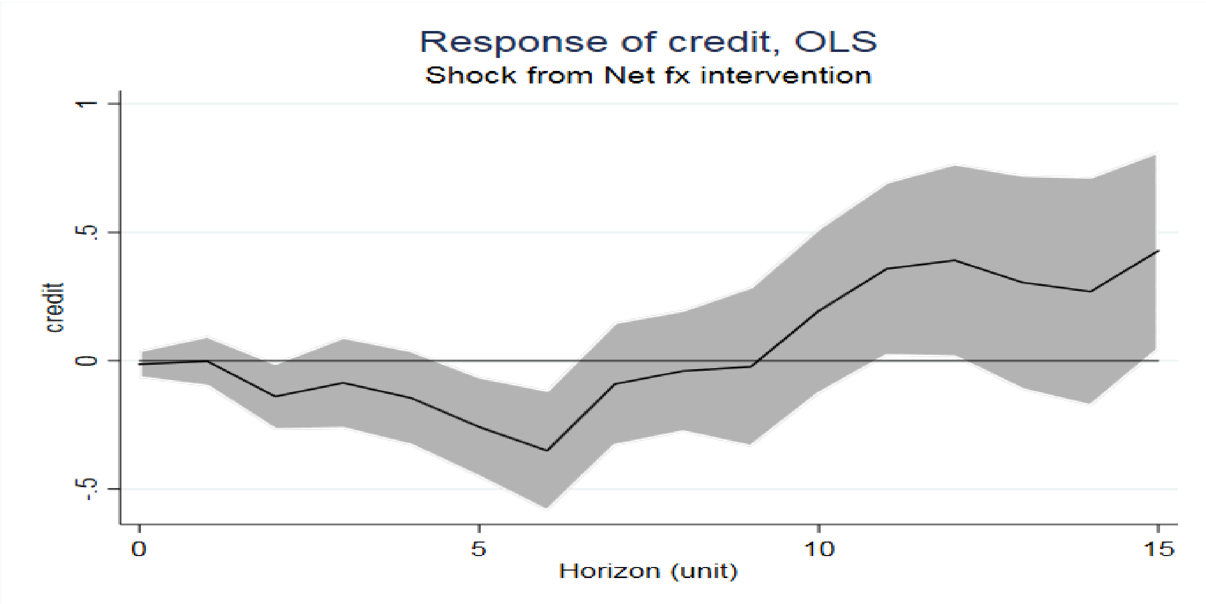
Using (4.16), Jorda (2005) reports that consistent and asymptotically normal estimates for A_j^h

for j = 1,....,k can be obtained. The advantages of this method are estimates can be obtained using the least squares and can be used for inference without asymptotic approximations. I also helps to compute impulse without specification and estimation of the underlying multivariate dynamic system. We augment (4.16) with exogenous terms by including control variables hence, the baseline model can be defined as in the equation below:

$$Y_{i,t+h} = \alpha_{h,i} + \lambda_h y_{i,t-1} + \beta_h FXI_{t-1} + \Gamma_h Q_{i,t-1} + \Omega_h E_{t-1} + \epsilon_{i,t+h}\ , \tag{4.17}$$

Where $Y_{i,t+h}$ is the cumulative flow of new firms' loans by bank i, the model will include a lagged dependent variable $y_{i,t-1}$ as specified above. The inclusion of this variable is aimed at capturing any persistence in the dependent variable. The matrix Q_i captures attributes of banks that provide credit to the private sector defined as the total assets, total capital and total liabilities. E also defines macro-financial variables. These variables include log-level of the VIX index, the change in bilateral exchange rate of the Ugandan shilling against the US dollar, the change in the policy rate, deviation of inflation from the Bank's target and net portfolio inflows and finally FXI_{t-1} capturing the net sterilised FX Intervention variable. Some of the variables included in the control variables describe the FX intervention function. It is from the estimates of β_h for the given time horizon that cumulative (IRF) of new credit subjected to FX intervention shock are produced.

Cumulative (IRF) from local linear projections regressions in 5 per cent confidence bands with robust standards errors clustered at on both cross-section and period. In Figure 4.2, we observe following a FX intervention shock, credit growth decreases in the first six months and recovers after the sixth month, becoming positive after the ninth month. These movements suggest credit growth is negative for a period of nine months, becoming positive after this period following a FX intervention shock. This shows a FX intervention shock has a negative impact



Note:The figure presents the cumulative Impulse Response Function(IRF) of an FX intervention shock of a first difference magnitude shock.The x-axis presents the months. The y-axis represents a change in credit.

Figure 4.2: Impact of FX intervention shock on credit growth in Uganda.

on credit growth.This decrease in credit growth is not persistent as one would expect.However, it still supports our first hypothesis. We naturally question through which channel(s) is credit affected. Literature suggests through the exchange rate, net portfolio inflows and crowding-out channels, FX interventions can impact on domestic credit growth.

4.4.1 Exchange rate channel

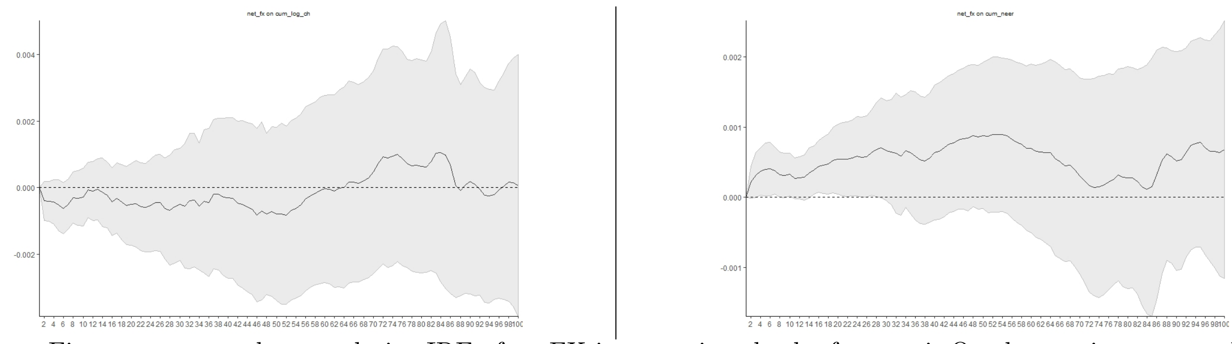
In this section, we examine the role of the exchange rate in the transmission of FX intervention shock on credit. In testing of the risk-taking channel of the exchange rate we explore the impact of net FX purchases[8] on the Nominal Effective Exchange Rate(NEER) and the bilateral exchange rate of the Ugandan shilling against the US dollar. The NEER is used as it measures the competitiveness of the local currency. Additionally, the Central Bank uses the USD for it FX interventions, capital inflows and outflows are typically in USD and we therefore employ the

[8]The difference between FX purchases and net FX purchases is that net fx purchases is net of sales on a given day of intervention.

UGX-USD exchange in the analysis. In order to avoid problems of endogeneity/simultaneity that may arise, daily figures of the exchange rate and NEER are used. We assume the exchange rate/NEER change can be explained by the FX interventions and its reaction function. The baseline model in (4.17) is rewritten as follows:

$$X_{i,t+h} = \alpha_{h,i} + \lambda_h x_{i,t-1} + \beta_h FXI_{t-1} + \Omega_h E_{t-1} + \epsilon_{i,t+h} \tag{4.18}$$

Where $X_{i,t+h}$ is the cumulative sum of x_i the log change in the NEER/shilling US dollar exchange rate, a lagged dependent variable $x_{i,t-1}$ is included and FXI_t that captures net FX intervention. Additionally, change in the policy rate and VIX index are included as control variables represented by E.



Note: Figures presents the cumulative IRF of an FX intervention shock of one unit.On the x-axis presents the number of trading days. The y-axis represents a percentage change in UGX-USD/NEER.

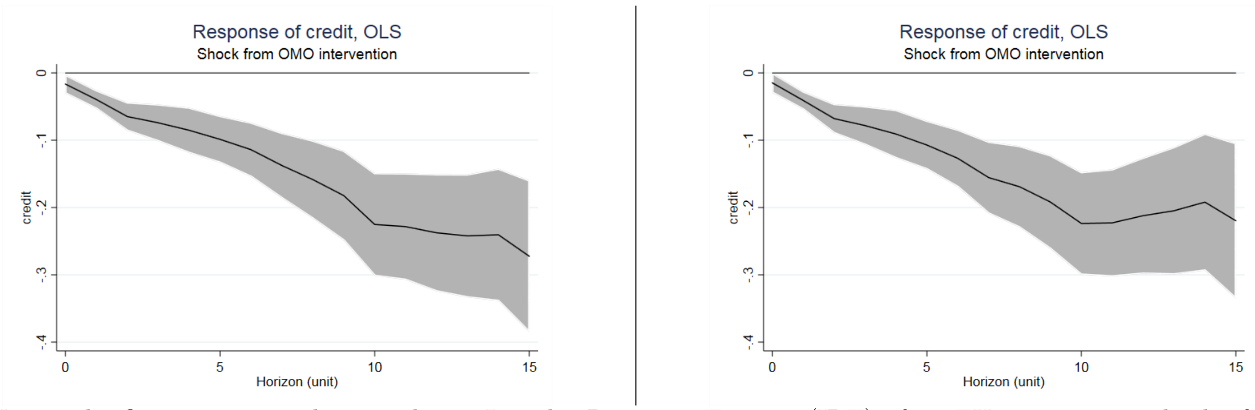
Figure 4.4: The cumulative response of NEER to Net FX interventions

In Figure 4.3 we consider the bilateral exchange of the shilling to US dollar to FX intervention and the results show that the impact of net FX intervention shock on the exchange rate of the shilling against the dollar is insignificant over the 100 trading days.This finding is in line with previous studies such as Montoro (2013) who reports that sterilised FX interventions has little impact on near-term nominal exchange rate expectations. In Figure 4.4 daily impulse response of FX intervention shock on the NEER, is used to test for robustness of the previous result.

In this empirical exercise, the regressions are run on a daily frequency for horizons up to 100 days, the impact on the NEER due to one unit shock to net FX intervention suggests that on average the shilling appreciates against the basket of currencies. This is largely driven by these currencies: US dollar, euro, Kenyan shilling, Indian rupees and United Arab Emirates Dirham. The weights attached to these currencies account for over 57 per cent of the total weights. This observation diverges from the previous finding on the UGX-USD exchange rate and a possible explanation is some of the currencies in the basket of currencies depreciated against the shilling and therefore on aggregate the shilling appreciated. However, FX interventions and capital movements are usually done in USD and we conclude FX intervention shocks on the UGX-USD exchange rate are insignificant. The result differs from a finding by Hofmann et al. (2019) who report a significant exchange rate channel in Peru. Although the model stipulates that the exchange rate is an important transmission channel, with the expectation that an appreciation of local currency should lead to increased lending, an insignificant transmission is observed in this paper. A possible explanation for this finding could be, what is the effect of increased dollarisation in Uganda as noted earlier, see footnote 4. This also indicates other operational channel(s) exist through which effects of FX interventions feed through to credit growth.

4.4.2 Crowding channel

In this section we test for "crowding-out" channel. The baseline model is adjusted by replacing the sterilised FX intervention variable with Open market Operations. This comes into play when banks' balance sheets are capital or leverage constrained, consequently, leading to lending restrictions. As the Central Bank supplies government securities through sterilisation leg of FX intervention, banks become capital constrained as more capital is allocated to the purchase of government securities. This further leads to a reduction in capital available for private sector lending hence, a decrease in private sector credit. In Figure 4.5, the response of new credit to a shock to open market operations suggests a significant and persistent decrease in credit growth over the period of observation. As noted in the model, an increase in OMO should decrease the growth of private sector credit. These impulse responses are in line with the stated hypothesis. In Figure 4.6 we experiment with repos, an open market operation instrument. We observed after a repos shock credit growth decreases significantly, however, the decline is more pronounced with OMO instruments. Repos is one of the main components of OMO instruments and have largely followed the same path as OMO. These results indicate that the crowding effect is operational in Uganda. Additionally, credit growth is Uganda is largely affected by the crowding out channel of monetary policy as seen in this empirical exercise.



Note: The figure presents the cumulative Impulse Response Function(IRF) of an FX intervention shock of 1 unit shock.On the x-axis presents the months. The y-axis represents a change in credit.

Figure 4.6: Monthly response of new credit growth to OMO/repos shock

4.5 Conclusion

In this chapter, we consider the impact of sterilisation FX intervention on credit growth in Uganda and the transmission mechanisms at work. Using linear local projection methodology as proposed by Jorda (2005) results show that FX intervention reduces credit growth in Uganda this is in line with a previous study by (Hofmann et al. 2019) who examine the impact of sterilised FX interventions in Peru. However, the decline in credit is not persistent as it lasts for a period of six months only.

We observe that sterilised FX intervention insignificantly affects the UGX-USD exchange rate. This finding goes against a previous paper by Hofmann et al. (2019) in Peru and our stated hypothesis. The hypothesis, states FX purchases are expected to depreciate the local currency. Although the model stipulates the exchange rate as one of the main transmission mechanisms, the empirical exercise fails to identify significant effects of sterilised FX shocks.

The impact of FX shocks on open market operations shows credit growth declines in a significant and persistent way suggesting a “crowding-out” channel is operational. The result shows, the crowding-out channel is the main mechanism through which sterilised FX intervention feed through to domestic credit. We therefore conclude that in Uganda the crowding-out channel is the main transmission mechanism of sterilised FX intervention as hypothesised.

FX interventions dampen credit growth and the instrument could be used in times of credit booms, as a way to moderate excess credit growth in the economy and as a consequence used a financial stability instrument. An area that needs further research could be what is the optimal policy mix that enables FX interventions to achieve financial stability and monetary policy objectives.

In the previous chapters, we find restrictive monetary policy, credit supply shocks and sterilised FX interventions negatively affect credit growth in Uganda. In the following chapter, we take a macroeconomic perspective and ask how these idiosyncratic credit supply shocks feed through to aggregate volatility in the country.

Chapter 5

Credit supply shocks and aggregate volatility: A network approach

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Abstract

In this paper we examine using a network approach, the transmission of idiosyncratic credit supply shocks to aggregate volatility in a developing economy. Our analytical framework is based on Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012). The model is extended to capture financial frictions and the role of intermediation via bank-lending. The economy comprises of households, banks and firms operating in an input-output system. In demonstrating the implications of our theoretical results in an empirical application to Uganda, an economy defined by high bank dependence and concentration in the banking industry. The empirical results suggest that idiosyncratic shocks to credit supply account for more than a third of the volatility observed at the aggregate level. Results from the counterfactual experiments show that configuration of the network plays a marginal part in determining aggregate volatility, whereas the architecture of financial intermediation has a bigger effect. In banking system environments characterised by financial frictions, the Herfindahl index is no longer a sufficient statistic for explaining the banking sector's contribution to aggregate volatility. From a policy perspective this paper opens up a debate on how financial intermediation should be organised with respect to its implications for aggregate volatility.

5.1 Introduction

There is by now extensive evidence on the relationship between financial conditions and macroeconomic outcomes, both in settings where the financial sector works to amplify real shocks and where shocks originate in the financial sector itself. However, the details of the underlying propagation mechanisms and their dependence on the anatomy of production and financial intermediation are still not fully understood. In this paper, we formally examine these issues from a network perspective with a particular focus on the transmission mechanism from idiosyncratic credit supply shocks to aggregate volatility.

Our analytical framework follows Acemoglu et al. (2012) and considers a static version of the multi-sector model in Long and Plosser (1983). We extend this environment to encompass financial frictions and a role for intermediation via bank lending. The economy is populated by households, banks and firms operating in an input-output system. Production displays decreasing returns to scale and is subject to a financial constraint, which requires firms to finance their wage bill in advance via bank loans. Banking services are differentiated so that loans from different banks are aggregated with a finite elasticity of substitution. Individual banks finance these loans by issuing deposits to households, whereby their funding costs are subject to shocks that are passed through into loan rates. Idiosyncratic shocks to banks' lending capacity therefore have real implications because they affect the price and volume of credit available to firms. The shocks are then further propagated through the economy's production network and ultimately affect aggregate output.

The model is intentionally kept simple in order to retain analytical tractability with results in closed-form. At its heart are two networks: the production network represented by the economy's input-output matrix $\mathbf{W}$, and the financial intermediation network $\mathbf{\Phi}$ summarising the financial links between banks and the industrial sectors. An important property of the intermediation network is that, generically, banks have links to multiple sectors so that idiosyncratic credit supply shocks become a direct source of comovement. Starting from this setup, we show that firms' production decisions are distorted under a binding financial constraint. Since the working capital constraint applies only to the wage bill, firms are induced to substitute their factor employment away from labour and towards intermediate inputs. And in consequence of this factor demand distortion, their combined expenditure share for labour and intermediate inputs falls short of what is dictated by decreasing returns alone. That is, both the intermediate input share and firms' profitability are increased relative to their technologically determined levels.

Building on this result, we go on to derive expressions for the equilibrium level of (the log of) aggregate output and its volatility. Aggregate output is characterised as a function of two objects: the distortion vector $\mathbf{\Theta}$, which collects the bank-level shocks weighted by their relevance for the financial intermediation network, and the distortion influence vector $\mathbf{d}$, which traces their propagation through the input-output network and ultimately maps them into final output. The volatility of aggregate output inherits these determinants, but it can equivalently be rewritten in terms of (i) a Herfindahl term proportional to the sum of squared bank market shares, and (ii) an additional outdegree correction term accounting for the sectoral interdependence beyond what is captured via bank market shares.

The outdegree correction term becomes relevant whenever financial frictions distort firms' input decisions. The important implication for such environments therefore is that the bank Herfindahl index is no longer a sufficient statistic for the banking system's contribution to aggregate volatility. This opens the door for normative questions about the desirable organisation of financial intermediation with respect to its implications for aggregate volatility. In a series of simple examples, we show under which conditions these considerations have bite and how they twist the usual recommendation of simply minimising the bank Herfindahl index.

We conclude by demonstrating the implications of our theoretical results in an empirical application to the case of Uganda, an economy characterised by high bank dependence and concentration in the banking industry. In a first step, we exploit credit registry data to provide an empirical estimate of the magnitude of bank-level credit supply shocks and their consequences for credit dynamics at the bank and sector level. The pattern of our empirical results supports the conclusion that idiosyncratic shocks to credit supply have real consequences for bank-dependent industrial sectors. In light of this evidence, we calibrate our theoretical model to capture the empirical features of the intermediation and production networks observed in Uganda. We then subject the calibrated economy to a number of counterfactual experiments focused on (i) the decomposition of the sources of aggregate volatility and (ii) the degree of amplification in the mapping from idiosyncratic shocks to aggregate outcomes. The key findings from this exercise are as follows.

The configuration of the production network $\mathbf{W}$ plays only a marginal role in the determination of aggregate volatility, whereas the architecture $\mathbf{\Phi}$ of financial intermediation has important effects. These effects are often visible in the bank Herfindahl index. But the bank Herfindahl index is not necessarily an appropriate indicator for aggregate volatility, in line with our theoretical results. Closely related to this observation is the question about the role of financial frictions for the degree of amplification of idiosyncratic shocks. Our theoretical model points at an increased intermediate input share and increased profit leakage as the principal consequences of financial frictions. A larger intermediate input share increases the network multiplier for the input-output system substantially – by a factor of 2.25 in our calibrated economy. Increased profit leakage, however, works in the opposite direction, illustrating the quantitative relevance of the outdegree correction term. The degree of amplification after accounting for both effects is thus diminished to a factor of about 1.38. Neverthless, when we square the estimated volatility of the credit supply shocks estimated from the credit registry data with the volatility of GDP in Uganda, we find that these idiosyncratic shocks alone can account for more than one third of the volatility recorded at the aggregate level. Owing to their granularity and to the propagation mechanism via the intermediation and production network, we thus find bank-level credit supply shocks to have sizeable real implications.

Related literature

Our work is related to three strands of literature. The first strand links network structure in production economies to the real economy. In the second we empirically illustrate how financial shocks feed to the economy and finally we focus on how bank size is important in the propagating systemic risks in the sector.

In the first strand, we examine the importance of network structure in production economies in the transmission of idiosyncratic shocks to the real economy through intersectoral linkages as a factor in the contagion:

Acemoglu et al. (2012) argue that in presence of intersectoral input-output linkages, idiosyncratic shocks at a microeconomic level can feed into aggregate fluctuations. The authors suggest that the structure of the network of the linkages affects the rate at which aggregate volatility decreases. The paper also manages to rank relationship between different sectors as suppliers to their direct and indirect customers using network analysis techniques. In a related paper Acemoglu, Ozdaglar and Tahbaz-Salehi (2017) and based on a multi-sector general equilibrium model show the interplay of idiosyncratic microeconomic shocks and input-output linkages contribute tail co-movement as large recessions cause significant declines in GDP and industrial activity.

Bigio and La'O (2020) introduce financial frictions in a static multisector framework in which production is undertaken in an input-output network and observe sectoral distortions feeding through to the aggregate level through the total productivity and labour wedge channels. They show during the 2008-09 financial crisis the US input-output structure increased financial distortions by a factor of two.

These papers highlight the importance of the network structure in a developed country setting.

We deviate from these papers by considering a developing country environment characterised by financial frictions.

Although, the above papers take a theoretical approach using network analysis to explain the contagion to the real economy, we note empirically the following papers consider an environment where credit supply shocks originate from the financial sector. Chava and Purnanandam (2011) explore the effect of Russian banking crisis as an exogenous shock on U.S banking system. They observe firms that primarily used bank capital suffered larger valuation losses translating into lower capital expenditure and lower profitability. Chodorow-Reich (2013) also examines the impact of bank lending frictions on employment outcome during 2008-9 financial crisis using fixed effects models. The paper finds that banking relationships are important and therefore there is a cost in switching to other lenders. The author establishes firms that had a banking relationship with less healthy lenders had a lower probability of obtaining a loan after the Lehman bankruptcy, paid higher interest rates and reduced employment. Kroszner, Laeven and Klingebiel (2007), investigates the impact of banking crises on industries dependent on bank credit and report sectors that rely on bank credit experience a greater reduction in value added during a bank crisis. These papers illustrate how shocks to the banking sector can feed through to the real economy. We differ from these papers by considering the impact of banking sector shock during normal times.

Following Gabaix (2011), a number of papers have examined the role of bank-specific shocks for the real economy, another strand considers the importance of bank size in propagating systemic risks in the sector. Buch and Neugebauer (2011) analyse whether shocks to loan growth at large bank impacts on real GDP growth using a measure of idiosyncratic shocks developed by Gabaix (2011). The authors find changes in lending have short-run effects on GDP. In a related paper, Bremus, Buch, Russ and Schnitzer (2018) examine both theoretically and empirically whether the presence of big banks affects macroeconomic outcomes. They show that big banks have a positive and significant relationship with macroeconomic outcomes such as GDP. Although, we do not explicitly consider the size of banks in our analysis, we are aware that the banking industry in Uganda is characterised as fore-mentioned and therefore the presence of few large banks could propagate the shocks. In this paper we consider how important are network structure in production economies in the transmission of idiosyncratic shocks to the real economy through intersectoral linkages. Our own empirical work complements the above papers with results for Uganda, 2012-2020. We therefore present evidence from a different environment, namely a developing economy where financial market are relatively less developed and subject to substantial financial frictions.

The remainder of this paper is organised as follows. Section 5.2 presents our theoretical model, whose properties are then analysed in Section 5.3. Section 5.4 contains the empirical application to the case of Uganda along with our counterfactual experiments. Section 5.5 concludes.

5.2 The model

We consider a static general equilibrium model of input-output trade within a network of industrial sectors subject to financial frictions. In line with some recent papers in the literature, we assume that bank loans are differentiated products.[1]

5.2.1 Economic environment

Each good in the economy is produced by one of n competitive sectors and can be used either for consumption or as an intermediate input for production in other sectors. Labour is the only primary factor and assumed in exogenous supply, normalised to unity, $L = 1$. The production

[1]There is a range of possible interpretations for this differentiation, most of them evolving around the services provided by banks in the process of lending. We should elaborate on this point.

technology for intermediate good firms in sector i is given by

$$q_i = (u_i)^\eta, \tag{5.1}$$

where u_i is an input composite, and $\eta \in (0,1)$ denotes the degree of decreasing returns to scale.[2] Let q_{ij} denote the intermediate inputs from sector j used in sector i to produce its output good q_i. The input composite u_i aggregates these intermediate inputs together with labour ℓ_i hired in sector i according to a Cobb-Douglas function,

$$u_i = \ell_i^\alpha \prod_{j=1}^{n} q_{ij}^{(1-\alpha)\omega_{ij}}, \tag{5.2}$$

where $\sum_{j=1}^n \omega_{ij} = 1$ so that the input aggregation displays constant returns. Intermediate good firms are competitive and take prices as given. A limited enforcement constraint forces them to finance their wage bill upfront with bank loans whose gross-of-interest volume cannot exceed a fraction ξ of their sales revenue. Notice, however, that this working capital constraint relates only to firms' wage payments, but not to their expenditure on intermediate inputs. The implicit assumption therefore is that trade credit to support the flow of intermediate inputs between sectors is available without frictions, while wage payments must be facilitated via bank credit.[3]

Sectoral output q_i can be used either for consumption c_i or as an intermediate input for production in other sectors,

$$q_i = c_i + \sum_{j=1}^{n} q_{ji}. \tag{5.3}$$

As in Acemoglu et al. (2012) and Jones (2013), the sectoral consumption goods c_i are aggregated into a single final good through a log-linear function (which can either represent the technology

[2] Decreasing returns naturally arise as a consequence of factors of production like capital that are (in the short-run) fixed or immobile across sectors.

[3] Bigio and La'O (2020) consider a related setting with exogenous working capital constraints where they allow only for bank credit but not for trade credit. Altinoglu (2020) and Luo (2020) consider economies with trade credit subject to endogenous financial constraints.

for final good production or household preferences over the aggregate consumption bundle C),

$$Y = C = \prod_{i=1}^{n} c_i^{\beta_i}, \tag{5.4}$$

where β_i denotes the expenditure share falling on sector i and $\sum_{i=1}^{n} \beta_i = 1$.

5.2.2 Banks

There are m banks providing differentiated loans to the intermediate good firms. This differentiation is associated with limited credit market competition whose ultimate source we leave unmodeled here. The theoretical literature typically links banks' market power to asymmetric information problems, long-term customer relationships, switching costs or spatial and regulatory considerations of bank reach.[4] Against this background, we take the limited substitutability across loans originated by different banks as a primitive of our model. Banks are owned by households and fund their working capital loans by issuing demand deposits, which are passed on by the firms to compensate workers for their labor supply. Deposits are remunerated at an exogenous gross interest rate R, which is common to all banks, consistent with perfect competition on the deposit market.

On top of the common cost of deposits, the funding cost facing an individual bank b is subject to an idiosyncratic shock $z_b \in (0, 1)$ relating to the operating cost of the bank's lending activity. The resulting variable cost of lending is thus bank-specific and passed on to the borrowing firms, resulting in a gross lending rate

$$r_b = \frac{R}{z_b} > R. \tag{5.5}$$

[4]Most microeconomic studies of financial intermediation consider market power as a distinctive feature of the banking industry (Freixas and Rochet, 1997), and it is empirically well-documented (Claessens and Laeven, 2004; Degryse and Ongena, 2008). Recent papers introducing heterogenous banks with differentiated loans and markups due to market power include Gerali, Neri, Sessa and Signoretti (2010), Mandelman (2010), Andres and Arce (2012), Bremus et al. (2018) and Corbae and D'Erasmo (2019).

Hence, for a given deposit rate R, the gross lending rate r_b varies inversely with the idiosyncratic cost shock z_b. Let x_{ib} denote the volume of loans from bank b to sector i, and let D_b denote the bank's deposit base. Taking account of the full variable cost of lending, zero profits in banking then imply

$$r_b \sum_{i=1}^{n} x_{ib} = RD_b, \tag{5.6}$$

or equivalently,

$$x_b = \sum_{i=1}^{n} x_{ib} = z_b D_b, \tag{5.7}$$

which can be interpreted as a balance sheet constraint restricting the bank's volume of funds x_b available for lending to firms. The pass-through of funding costs to borrowers in the form of increased lending rates is possible due to imperfect competition on the loan market. In a closely related paper, Bremus et al. (2018) provide a micro-foundation for this mechanism within a model with imperfect competition among heterogeneous banks charging endogenous markups in the face of a search friction. Specifically, we assume that bank loans are relationship-specific and thus differentiated products with a finite elasticity of substitution across loans originating from different banks. In the following, we presume a Cobb-Douglas aggregation with unitary elasticity across loans,

$$x_i = \prod_{b=1}^{m} x_{ib}^{\phi_{ib}}, \tag{5.8}$$

where $\sum_{b=1}^{m} \phi_{ib} = 1$. Accordingly, the effective loan volume available to intermediate good firms operating in sector i is given by the weighted geometric mean of loans x_{ib} obtained from individual banks, where the weights ϕ_{ib} capture the importance of bank b in financing sector i. Finally, let $D = \sum_{b=1}^{m} D_b$ denote the aggregate volume of deposits created by the banking sector.

5.2.3 Firms

Intermediate good firms are competitive and take prices and the technology specified in (5.1) and (5.2) as given. In addition, they face a financial constraint, which forces them to finance their wage bill $w\ell_i$ (but not their expenditure on intermediate inputs) upfront with bank loans whose gross-of-interest volume cannot exceed a fraction $\xi \in (0, 1)$ of their sales revenue. That is,

$$w\ell_i = x_i = \prod_{b=1}^{m} x_{ib}^{\phi_{ib}}, \tag{5.9}$$

$$r_i x_i \leq \xi p_i q_i, \tag{5.10}$$

where the overall cost of financing capital is based on the optimal combination of bank loans x_{ib} and satisfies

$$r_i = \prod_{b=1}^{m} \left(\frac{r_b}{\phi_{ib}} \right)^{\phi_{ib}}. \tag{5.11}$$

Notice again that this presumes a Cobb-Douglas aggregation of bank loans as in (5.8). The problem faced by intermediate good firms then is

$$\max_{x_i, \ell_i, q_{ij}} \pi_i = p_i \left(\ell_i^{\alpha} \prod_{j=1}^{n} q_{ij}^{(1-\alpha)\omega_{ij}} \right)^{\eta} - r_i x_i - \sum_{j=1}^{n} p_j q_{ij}, \tag{5.12}$$

subject to (5.9) and (5.10). We assume $\xi < \eta\alpha$ so that financial constraint (5.10) is binding.

Lemma 1 *Suppose $\xi < \eta\alpha$. Given the wage rate w, the vector of sectoral prices $\mathbf{p} = [p_1, ..., p_n]'$ and the vector of interest rates $\mathbf{r} = [r_1, ..., r_m]'$, the factor and loan demand of the representative, financially constrained firm in sector i satisfy*

$q_{ij} = \zeta(1-\alpha)\omega_{ij}p_i$

$q_i \frac{}{p_j,}$

where $r_i = \prod_{b=1}^{m} \left(\frac{r_b}{\phi_{ib}}\right)^{\phi_{ib}}$ and $\frac{\xi}{\alpha} = \chi < \eta < \zeta = \frac{1-\xi}{1-\eta\alpha}\eta$. The firm's total expenditure satisfies

$$r_i x_i + \sum_{j=1}^{m} p_j q_{ij} = \left[\chi\alpha + \zeta(1-\alpha)\right] p_i q_i < \eta p_i q_i. \tag{5.13}$$

The compound parameter $\chi < \eta$ captures the effective tightness of the financial constraint, which we interpret as an indicator of financial development. Taking this parameter as given, equation (**??**) indicates that that sector i's demand for loans from bank b varies inversely with the lending rate r_b. At the same time, the expression retains the limited substitutability across loans originated by differentiated banks.

More generally, the results summarised in Lemma 1 indicate that a binding financial constraint distorts firm decisions in three dimensions. The distortions are best understood relative to the unconstrained benchmark where, given decreasing returns to scale, a firm's total expenditure amounts to a fraction $\eta < 1$ of its revenue. First, since the working capital constraint applies only to the wage bill, the immediate effect is that firms have to economise on their gross-of-interest expenditure on wages. The associated expenditure share now amounts only to $\xi = \chi\alpha < \eta\alpha$ of firm revenue. Second, since firm revenue can be increased by expanding the use of intermediate inputs which are not subject to the financial constraint, firms seek to relax their financial constraint by increasing the overall expenditure share on intermediate inputs to $\zeta(1-\alpha) > \eta(1-\alpha)$. There is thus a technologically inefficient substitution of inputs away from labor and towards intermediate inputs. Third, the cumulative effect of these demand distortions for labour and intermediates is that firms have to limit their expenditure below what is dictated by decreasing returns alone, $\chi\alpha + \zeta(1-\alpha) < \eta$. The financial constraint thus leads firms operate at an inefficient scale. It is straightforward to show that this distortion is increasing in the labour share.

Lemma 2 *Suppose $\xi < \eta\alpha$. Then the shortfall of total expenditure relative to the volume implied by decreasing returns to scale is increasing in α. Formally,*

$$\frac{d}{d\alpha}\left[\chi\alpha + \zeta(1-\alpha)\right] < 0.$$

5.2.4 Equilibrium

Recall from (5.3) and (5.4) that sectoral output can be used either for consumption or as an intermediate input for production in other sectors, and that final output coincides with aggregate consumption,

$$q_i = c_i + \sum_{j=1}^{n} q_{ji},$$
$$Y = C = \prod_{i=1}^{n} c_i^{\beta_i}.$$

With P denoting the aggregate price level, expenditure for final consumption goods from sector i is then given by

$$p_i c_i = \beta_i P C, \tag{5.14}$$

and the aggregate price level under Cobb-Douglas aggregation is

$$P = \prod_{i=1}^{n} \left(\frac{p_i}{\beta_i}\right)^{\beta_i}, \tag{5.15}$$

which is normalized to one, $P = 1$. A competitive equilibrium for the given economy is defined as follows.

Definition 1 *A competitive equilibrium of the economy with m banks and n intermediate good sectors consists of prices w, R, $\mathbf{p} = [p_1, ..., p_n]'$, $\mathbf{r} = [r_1, ..., r_m]'$ and quantities $\ell = [\ell_1, ..., \ell_n]'$, D, $\mathbf{c} = [c_1, ..., c_n]'$, $\mathbf{q} = [q_1, ..., q_n]'$, $\mathbf{x} = [x_1, ..., x_n]'$ with $\mathbf{q_i} = [q_{i1}, ..., q_{in}]'$ and $\mathbf{x_i} = [x_{i1}, ..., x_{im}]'$ for all sectors $i = 1, ..., n$ such that:*

(i) the consumption allocation $\mathbf{c}$ is consistent with (5.4);

(ii) interest rates $\mathbf{r}$ satisfy (5.5);

(iii) the intermediate good firm allocation ℓ_i, q_{ij} and x_{ib} solves problem (5.12);

(iv) markets clear, that is,

$$\sum_{i=1}^{n} \ell_i = L = 1, \qquad w \sum_{i=1}^{n} \ell_i = w = D, \qquad q_i = c_i + \sum_{j=1}^{n} q_{ji}, \qquad \sum_{i=1}^{n} x_{ib} = x_b;$$

(v) prices aggregate, that is,

$$P = \prod_{i=1}^{n} \left(\frac{p_i}{\beta_i} \right)^{\beta_i} = 1, \qquad r_i = \prod_{b=1}^{m} \left(\frac{r_b}{\phi_{ib}} \right)^{\phi_{ib}}.$$

5.3 Analysis

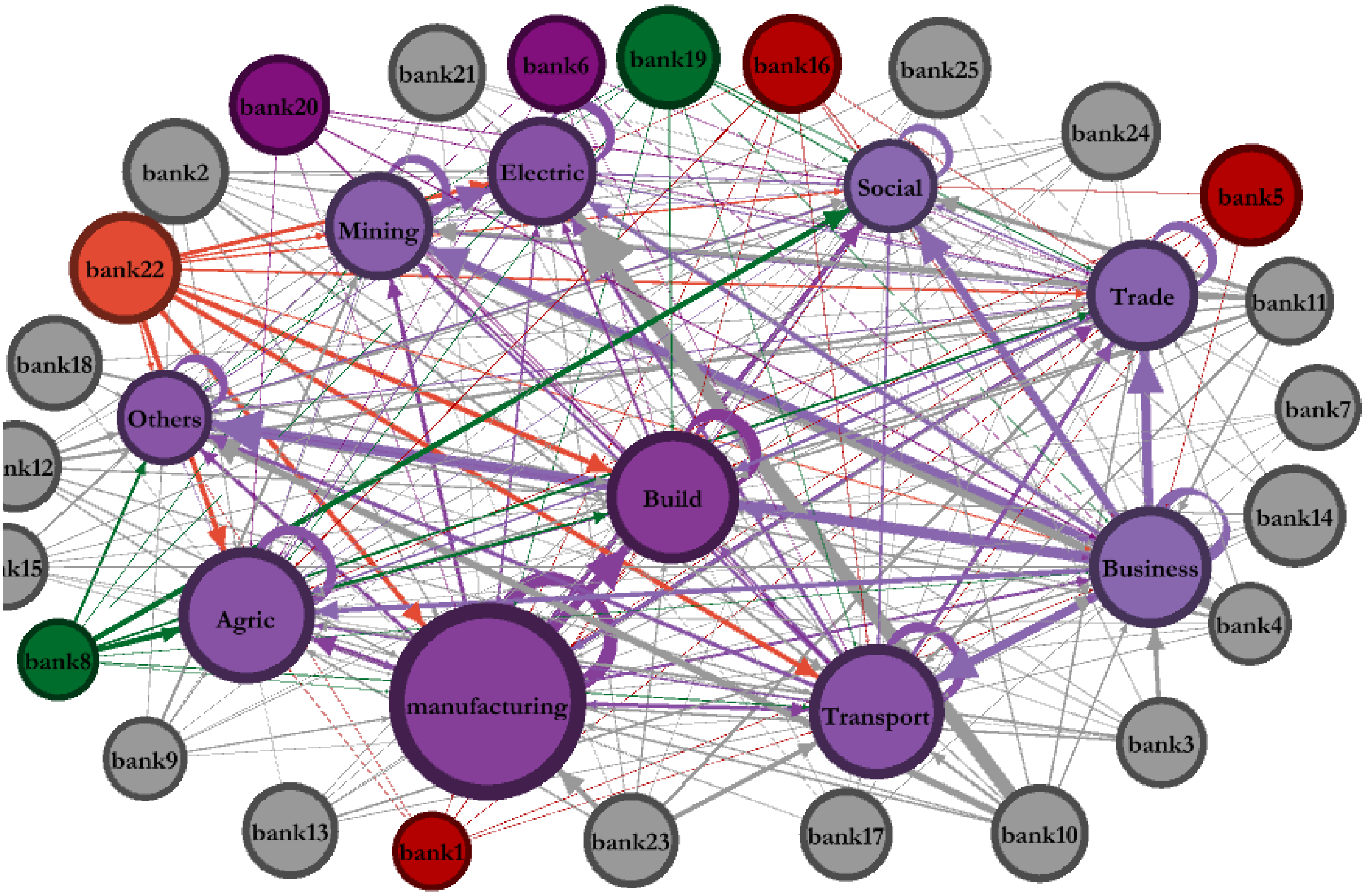

Figure 5.1: A combination of the Input-Output($\mathbf{W}$) and Intermediation($\mathbf{\Phi}$) Matrices

In the above Figure 5.1 we provide a graphical illustration of the linkages between the input-output($\mathbf{W}$) matrix [5] and the intermediation($\mathbf{\Phi}$) matrix. In Fig 5.1 the direction of the arrows show the relationship between banks and sectors of the economy. The thickness of these arrows

[5] For detailed sector classification please see appendix Table C.1.1

shows the strength of these relationships. Arrows that originates from a given bank to given sector implies the bank in question lends to that sector. Likewise if the arrow originates from a given sector to another sector this shows the sector in question provides inputs to that sector. The figure also illustrates cases where sector provide inputs to itself sector. To begin, it is convenient to define a number of important primitives. Let the $n \times m$ matrix $\mathbf{\Phi}$ collect the coefficients for the given bank-sector relations,

$$\mathbf{\Phi} \equiv \begin{bmatrix} \phi_{11} & \dots & \phi_{1m} \\ \vdots & \ddots & \vdots \\ \phi_{n1} & \dots & \phi_{nm} \end{bmatrix}$$

with typical element ϕ_{ib}, capturing the importance of bank b in financing sector i. Similarly, let $\mathbf{W}$ denote the $n \times n$ input-output matrix,

$$\mathbf{W} \equiv \begin{bmatrix} \omega_{11} & \dots & \omega_{1n} \\ \vdots & \ddots & \vdots \\ \omega_{n1} & \dots & \omega_{nn} \end{bmatrix}$$

collecting the intermediate input shares ω_{ij} across sectors. Based on the intersectoral dependence embodied in $\mathbf{W}$, we obtain the *influence vector*,[6] defined as

$$\mathbf{v} = \alpha \left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}'\right]^{-1} \beta. \tag{5.16}$$

Intuitively, element v_i of the influence vector captures the importance of sector i for aggregate outcomes, taking into account the effects of propagation through the network of input-output linkages across sectors (Acemoglu et al., 2012). Consequently, the influence vector is characterised in terms of ζ, which captures sectors' (endogenous) dependence on intermediate inputs (cf. Lemma 1).

[6] See Appendix C.1.3 for a derivation of the influence vector and its relation to the sectoral sales vector.

In an economy where firms operate under constant returns to scale and are not subject to financial frictions ($\eta = 1$ and $\xi \geq \eta\alpha$), the influence vector can be interpreted in terms of the share of labor (the only primary input into production) assigned to the sectors: Each sector purchases intermediate inputs and hires labor, which is then transformed into intermediate output and – by way of the intersectoral input-output linkages – ultimately into final output. Thus, the influence vector provides a measure of sectors' importance in the mapping from labour inputs to final output, with $\sum_{i=1}^{n} v_i = 1$. That is, the influence vector coincides with the sectoral sales vector, and the v_i correspond to the Domar weights.

In the economy at hand, however, firms operate under decreasing returns to scale ($\eta < 1$) and are financially constrained ($\xi < \eta\alpha$). Under decreasing returns, firms make profits, which are paid to households in the form of dividends rather than recycled within the input-output network for purchases of intermediate inputs. There is thus 'profit leakage' (Bigio and La'O, 2016). Under financial frictions, the allocation is further modified because the scale of firms' production as measured by the share of expenditure relative to sales is reduced below what is dictated by decreasing returns alone (cf. Lemma 1), so that the share of profits increases further. On the other hand, in an effort to relax their financial constraint, firms increase the share of their expenditure on intermediate inputs relative to sales to $\zeta(1-\alpha) > \eta(1-\alpha)$. The joint effect of these forces is to distort the influence vector away from the sales vector. In particular, we have

$$\sum_{i=1}^{n} v_i = \frac{\alpha}{1-\zeta(1-\alpha)},$$

which is generally different from one. Notice that $\frac{\alpha}{1-\zeta(1-\alpha)} > 1$ holds if $\zeta > 1$, which is true provided the extent of financial frictions as captured by the shortfall of ξ below $\eta\alpha$ is sufficiently strong relative to the extent of decreasing returns to scale $\eta < 1$. Formally, $\zeta = \frac{1-\xi}{1-\eta\alpha}\eta > 1$ if $\frac{1-\xi}{1-\eta\alpha} > \frac{1}{\eta}$. By contrast, under moderate financial frictions, we have $\zeta < 1$ and hence $\frac{\alpha}{1-\zeta(1-\alpha)} < 1$. Accordingly, depending on their relative strength, decreasing returns and financial frictions can work to amplify (attenuate) the importance of individual sectors for aggregate outcomes because they increase (limit) the use of intermediate inputs relative to sales and hence augment (contain) the propagation of changes at the sector level through the input-output network. We summarise our findings, which resonate results in Bigio and La'O (2016), in the following Proposition.

Proposition 1 *The elements of the the influence vector* $\mathbf{v}$ *are given by*

$$v_i = \alpha \frac{p_i q_i}{Y}.$$

Under constant returns to scale ($\eta = 1$) *and absent financial frictions* ($\xi \geq \eta\alpha$), $\zeta = 1$ *and the* v_i *coincide with the Domar weights (the sectoral shares of total intermediate good sales), that is,*

$$\sum_{i=1}^{n} v_i = 1.$$

Otherwise, when $\zeta \neq 1$, *this equivalence is lost and*

$$\sum_{i=1}^{n} v_i = \frac{\alpha}{1 - \zeta(1 - \alpha)} \neq 1.$$

For all scenarios in Proposition 1, the influence vector remains crucial in the expressions for firms' equilibrium demand for intermediate inputs and loans. They are given by

$$q_{ij} = \zeta(1 - \alpha)\omega_{ij} q_j \frac{v_i}{v_j}$$

and

$$x_{ib} = \frac{\phi_{ib} v_i}{\sum_{b=1}^{m} \sum_{i=1}^{n} \phi_{ib} v_i} z_b D,$$

where z_b is the idiosyncratic cost shock for bank b and $D = \sum_{i=1}^{n} w\ell_i = w$ by clearing on the market for working capital loans. But despite this importance, the influence vector is not in itself a sufficient statistic for the characterisation of aggregate outcomes in the presence of financial frictions. Instead, this requires consideration of the *distortion influence vector*,[7] defined as

$$\mathbf{d} = \alpha \left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}'\right]^{-1} \beta. \tag{5.17}$$

Comparison of the definition of the distortion influence vector in (5.17) with that of the influence vector in (5.16) reveals an almost identical structure – up to the difference between ζ and η. Thus, different from the influence vector, the distortion influence vector is defined not with reference to the importance of intermediate input flows, but instead in terms of the returns-to-scale parameter η. At a deeper level, however, it turns out that the mapping between $\mathbf{v}$ and $\mathbf{d}$ depends in a non-trivial way on the structure of the input-output matrix $\mathbf{W}$. In detail, we have

$$\mathbf{d}' = \mathbf{v}'\mathbf{M},$$

with

$$\mathbf{M} = \left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}\right]\left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}\right]^{-1}. \tag{5.18}$$

Notice in particular that it is generally *not* possible to write $\mathbf{M}$ as a linear matrix function of the input-output matrix $\mathbf{W}$. Accordingly, the mapping $\mathbf{M}$ is generally different from a simple rescaling of $\mathbf{v}$ into $\mathbf{d}$. Instead, it depends explicitly on the input-output matrix $\mathbf{W}$; that is, the sectoral interdependence embodied in the input-output network matters.[8]

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[7] See Appendix C.1.5 for a derivation of the distortion influence vector.

[8] A trivial exception is the case when $\mathbf{W} = \mathbb{I}$ so that each sector operates in isolation without any intermediate inputs flows between sectors. Then, $\mathbf{M}$ degenerates to a scaling factor, $\mathbf{M} = \frac{1-\zeta(1-\alpha)}{1-\eta(1-\alpha)}\mathbb{I}$. However, this simplification of $\mathbf{M}$ to a scaling factor is impossible in the presence of sectoral interdependence via intermediate

Intuitively, the characterisation of aggregate outcomes recurs on the distortion influence vector with its key parameter η (rather than ζ) because, unlike productivity shocks, the distortions z_b do not affect firms' production frontier. Firms' (efficient) production scale is therefore determined by the returns-to-scale parameter η, and this is what ultimately matters for the aggregate consequences of distortions in financing the intersectoral production network. On the other hand, the flow of intermediate inputs within the input-output network is still governed by the expenditure share parameter ζ, which is endogenous to the tightness of financial constraints (cf. Lemma 1) but does otherwise not interact with the idiosyncratic bank shocks z_b. In consequence, the influence vector $\mathbf{v}$ has an effect on the level of final output, whereas the aggregate impact of financial distortions z_b can be traced via the distortion influence vector $\mathbf{d}$. The following Proposition details this further.

Proposition 2 *In equilibrium, the natural logarithm of final output is given by*

$$\ln Y = \Gamma + \eta \sum_{i=1}^{n} \left[d_i \sum_{b=1}^{m} \phi_{ib} \ln \left(\phi_{ib} z_b \right) \right],$$

where Γ collects terms constant in z_b, and where ϕ_{ib} and z_b denote elements of the intermediation matrix $\mathbf{\Phi}$ and idiosyncratic bank shocks, respectively. As $\sum_{i=1}^{n} d_i \leq \sum_{i=1}^{n} v_i$, the equilibrium allocation is generically inefficient.

In compact notation, the expression from Proposition 2 can be written as

$$\ln Y = \Gamma + \eta \mathbf{d}' \mathbf{\Theta},$$

where the constant term Γ is determined via the influence vector $\mathbf{v}$,[9] and where the distortion

inputs.

[9] That is, we have $\Gamma = \Gamma(\mathbf{v})$; see the proof of Proposition 2.

vector

$$\mathbf{\Theta} \equiv \begin{bmatrix} \sum_{b=1}^{m} \phi_{1b} \ln(\phi_{1b} z_b) \\ \vdots \\ \sum_{b=1}^{m} \phi_{nb} \ln(\phi_{nb} z_b) \end{bmatrix}$$

collects the bank-level shocks z_b weighted by their relevance for the financial intermediation network $\mathbf{\Phi}$. Accordingly, the organisation of financial intermediation, as captured by $\mathbf{\Phi}$, has a direct level effect on final output,[10] and the quantitative relevance of this effect for aggregate production depends on the distortion influence vector $\mathbf{d}$. Moreover, since $\sum_{i=1}^{n} d_i \leq \sum_{i=1}^{n} v_i = \frac{\alpha}{1-\zeta(1-\alpha)}$, the equilibrium allocation is inefficient, which has two sources.

First, the inefficiency reflects the misallocation arising due to the input substitution described in Lemma 1, which distorts the aggregation of inputs in (5.2). Second, the idiosyncratic credit supply shocks z_b generally affect the intermediate goods sectors in an asymmetric fashion, which is governed by the particular cross-sectional pattern of shocks $\{z_b\}$ and their the propagation via the network of bank-sector relations $\mathbf{\Phi}$. Since the production technology (5.1) displays decreasing returns to scale, the resulting dispersion in the scale of sectoral production activity is inefficient. The distortion vector $\mathbf{\Theta}$ captures these distortions, and the distortion influence vector $\mathbf{d}$ traces their propagation through the input-output network and ultimately maps them into final output. Specifically, element d_i of the distortion influence vector captures the importance of sector i for the transmission of credit supply shocks into the production network. Notice, however, that in the considered environment with exogenous labor supply, inefficiency cannot materialise in terms of the supply of primary inputs, but exclusively in terms of reduced

[10] Even absent shocks (that is, when $z_b = 1$ for all banks b), the level effect arises due to the finite-elasticity aggregation of loans in (5.8), whereby the fact that this is presumed to happen with an unitary elasticity is not important in itself. To understand the mechanics, notice from the expression for $\mathbf{\Theta}$ that the contribution of sector i to $\ln Y$ depends on $\sum_{b=1}^{m} \phi_{ib} \ln(\phi_{ib})$, or equivalently, $\ln\left\{\Pi_{b=1}^{m} (\phi_{ib})^{\phi_{ib}}\right\}$. The structure of this Cobb-Douglas aggregator results from firms' optimal demand for loans, given the weights ϕ_{ib}. In a situation where (risk-neutral) firms could instead choose these weights, they would opt for complete concentration, that is, for obtaining the entirety of their loans from one single bank. This rationale for concentration is driven by the benefit from rationalising on the need to aggregate different loans subject to a finite elasticity of substitution.

aggregate productivity.[11]

Moving on from the level of final output, we now turn to analyse the aggregate volatility generated by idiosyncratic bank-level shocks. This requires consideration of two key objects. First, the vector of *bank outdegrees* o_b, whose entry for bank b accumulates its funding shares across all industrial sectors,

$$o_b = \sum_{i=1}^{n} \phi_{ib}. \tag{5.19}$$

Second, the vector of *bank market shares* s_b, defined as the ratio of the loans D_b issued by bank b over the aggregate volume of loans extended by the whole banking system, $D = \sum_{b=1}^{m} D_b$. Using this definition, the market share of bank b can be related to the influence vector (see Appendix C.1.4),

$$s_b = \frac{D_b}{D} = \frac{\sum_{i=1}^{n} \phi_{ib} v_i}{\sum_{b=1}^{m} \sum_{i=1}^{n} \phi_{ib} v_i}. \tag{5.20}$$

Bank market shares are an important – but generally not the only – factor explaining aggregate volatility, as detailed in the following Proposition.

Proposition 3 *Suppose all banks have the same distribution of shocks, $\sigma_b = \sigma$, and the shocks z_b are independent across banks. In equilibrium, the variance of the natural logarithm of final output is then given by*

$$\begin{aligned} var[\ln Y] &= \sigma^2 \eta^2 \sum_{b=1}^{m} \left(\sum_{i=1}^{n} d_i \phi_{ib} \sum_{j=1}^{n} d_j \phi_{jb} \right) \\ &= \sigma^2 \eta^2 \sum_{b=1}^{m} \left(\left(\frac{\alpha}{1 - \zeta(1-\alpha)} \right) s_b + \left(\sum_{i=1}^{n} \delta_i \phi_{ib} \right) \right)^2. \end{aligned}$$

where $s_b = \frac{D_b}{D}$ denotes the market share of bank b, and where $\delta_i \equiv d_i - v_i$ can be approximated,

[11] In the terminology of Bigio and La'O (2020), there is a loss of total factor productivity (misallocation), but no labour wedge (distortion of primary input supply).

to the first-order, as

$$\delta_i \approx (\eta - \zeta)(1-\alpha)\sum_{j=1}^{n} v_j \omega_{ji} \leq 0.$$

Similar to Proposition 2, the first line in the expression for $var[\ln Y]$ in Proposition 3 makes clear that the key determinants of aggregate volatility are the distortion vector $\mathbf{\Theta}$ and the distortion influence vector $\mathbf{d}$. The second line in this expression instead establishes that the mapping from idiosyncratic bank-level volatility to aggregate volatility generally depends on two terms: (i) a *Herfindahl term* proportional to the sum of squared bank market shares, and (ii) an *outdegree correction term*, which interacts the vector of bank outdegrees o_b with the vector of sectoral differences $\delta_i \equiv d_i - v_i$ and thus accounts for the sectoral interdependence beyond what is captured directly via the influence vector. From equation (5.20), we can infer that the Herfindahl term, that is, the sum of squared bank market shares, can be computed based on the influence vector $\mathbf{v}$. But to the extent that $\mathbf{v}$ differs from the distortion influence vector $\mathbf{d}$, the Herfindahl term alone fails to account for the correct mapping from idiosyncratic to aggregate volatility, which also requires consideration of the correction term. Indeed, as seen from the definition $\delta_i \equiv d_i - v_i$, the outdegree correction term emerges exactly due to the divergence of the distortion influence vector $\mathbf{d}$ from the influence vector $\mathbf{v}$. To better understand the substance of the Proposition, it is useful to consider a number of special cases.

First, suppose the production technology (5.1) displays constant returns to scale ($\eta = 1$) and financial frictions are irrelevant ($\xi \geq \eta\alpha$). In this friction-less economy, there is no need for firms to distort their input mix between capital and intermediate goods so that $\zeta = \eta = 1$ and $\delta = 0$. The variance expression from Proposition 3 thus degenerates to

$$var[\ln Y] = \sigma^2 \sum_{b=1}^{m} s_b^2.$$

Accordingly, aggregate volatility is equal to the product of idiosyncratic volatility and the

Herfindahl index of bank market shares (cf. Gabaix, 2011). From the expression for s_b in (5.20) it is clear that the bank market share embodies the structure of the input-output network $\mathbf{W}$ (via the sectoral influences v_i) and the intermediation network $\mathbf{\Phi}$ (via the bank-sector coefficients ϕ_{ib}). However, given the Herfindahl index, the details of neither $\mathbf{W}$ nor $\mathbf{\Phi}$ matter for aggregate volatility (cf. Bigio and La'O, 2020). In other words, even though the intermediation matrix $\mathbf{\Phi}$ determines the way financial shocks hit the economy and the input-output network $\mathbf{W}$ plays an important role in their propagation, the structure of bank market shares s_b as captured by the Herfindahl index is a sufficient statistic for tracing the relevance of bank-specific shocks for aggregate volatility. That is, $\mathbf{W}$ and $\mathbf{\Phi}$ play no role beyond pinning down the bank size distribution. This is a reflection of *Hulten's theorem* (Hulten, 1978) which states in a production context that, in efficient economies, the impact of an idiosyncratic shock at the micro level is equal to the relevant unit's sales share of GDP.[12]

Next, continue to assume that financial frictions play no role ($\xi > \eta\alpha$), but allow for decreasing returns to scale ($\eta < 1$). As before, there is no input substitution, implying $\zeta = \eta < 1$. Aggregate volatility can then again be characterised in terms of the Herfindahl index of bank market shares, now with an additional scaling term which arises because firms' expenditure share on intermediate inputs generally amounts to $\eta(1-\alpha) < (1-\alpha)$. It is now given by

$$var[\ln Y] = \sigma^2\eta^2 \sum_{b=1}^{m} \left(\left(\frac{\alpha}{1-\eta(1-\alpha)} \right) s_b \right)^2 = \sigma^2 \sum_{b=1}^{m} \left(\left(\frac{\eta\alpha}{1-\eta(1-\alpha)} \right) s_b \right)^2 .$$

Thus, as $\left(\frac{\eta\alpha}{1-\eta(1-\alpha)}\right) < 1$, aggregate volatility is now dampened. This is because of *profit leakage*: firms' sales revenues are now in part diverted from the propagation within the input-output system and rebated to households in the form of profits. In consequence, the role of the input-output network as a source of amplification is reduced. However, conditional on a given Herfindahl index of bank market shares, the network architecture embodied in $\mathbf{W}$ and $\mathbf{\Phi}$ continues to have no influence on aggregate volatility.

[12]Key to the derivation of Hulten's theorem are equilibrium efficiency and the envelope theorem. It may thus not hold in inefficient economies like the one considered here when $\eta < 1$ and $\xi > \eta\alpha$.

This result is finally broken when financial frictions are sufficiently strong to make them relevant for firms' input decisions ($\xi > \eta\alpha$). By Lemma 1, firms will then inefficiently substitute inputs away from labor and towards intermediate goods. With firms' expenditure share on intermediate inputs given by $\zeta(1-\alpha)$, the cofactor in the Herfindahl term is now given by $\left(\frac{\alpha}{1-\zeta(1-\alpha)}\right)$. As seen before, this cofactor exceeds (falls short of) one when financial frictions are sufficiently strong (moderate) relative to the extent of decreasing returns to scale; accordingly, the fundamental role of bank market shares s_b for aggregate fluctuations is amplified (dampened). Importantly, however, the effects of sectoral interdependence via spending on intermediate inputs as captured by parameter ζ are different from the extent of profit leakage governed by η. Indeed, Lemma 1 established $\eta < \zeta$, and as a consequence, the Herfindahl term overstates the contribution of idiosyncratic shocks to aggregate volatility.[13] This leads to the emergence of the additional outdegree correction term.

The nature of the outdegree correction term becomes clear from the approximation of δ_i in Proposition 3. As $\eta < \zeta$, the correction term is generally negative. The magnitude of this adjustment depends on $\sum_{j=1}^{n} v_j \omega_{ji}$, that is, on the importance of individual sectors i as suppliers to the other sectors j, scaled by these sectors' influence v_j. Hence, sectors that are important as suppliers of intermediate inputs get assigned a lower weight in the determination of the volatility of aggregate output. Similarly, the weight adjustment is also relevant for banks whose contribution to aggregate volatility is no longer captured by their market shares s_b and the corresponding simple Herfindahl index. Instead, as seen from the outdegree correction term $\sum_{i=1}^{n} \delta_i \phi_{ib}$, banks which lend to more important sectors get assigned a lower weight; that is, bank size is punished less if it is the result of lending to important sectors. The underlying notion of sectoral importance is again captured via the difference vector δ, which incorporates the full structure of the input-output matrix $\mathbf{W}$.

[13] In detail, the Herfindahl term accounts for the increased intermediate input share $\zeta(1-\alpha)$ under financial frictions, which leads to an increased network multiplier. But it fails to account for the increased extent of profit leakage as measured by the reduced overall expenditure share $\chi\alpha + \zeta(1-\alpha)$ (cf. Lemma 1).

In addition to the input-output matrix $\mathbf{W}$, the outdegree correction term $\sum_{i=1}^{n} \delta_i \phi_{ib}$ also recurs on the intermediation matrix $\mathbf{\Phi}$. Intuitively, the term $\sum_{i=1}^{n} \delta_i \phi_{ib}$ accounts for the part of bank b's contribution to aggregate volatility that has been incorrectly captured by its market share s_b; evidently, this contribution is determined by the relevant bank-sector links ϕ_{ib}. In consequence, also the intermediation matrix $\mathbf{\Phi}$ plays a key role in shaping aggregate volatility. One interesting aspect here is that, through $\mathbf{\Phi}$, idiosyncratic bank shocks z_b induce a correlation structure for the effective financial distortions the production network is subject to. This is readily seen from the distortion vector $\mathbf{\Theta}$, where an idiosyncratic shock z_b to bank b shows up as a distortion for all sectors i which have an existing lending relationship $\phi_{ib} > 0$ with that bank. Thus, credit supply shocks are naturally correlated across sectors. The financial intermediation network $\mathbf{\Phi}$ is therefore a second source of co-movement in addition to the input-output linkages embodied in $\mathbf{W}$.

5.3.1 An example

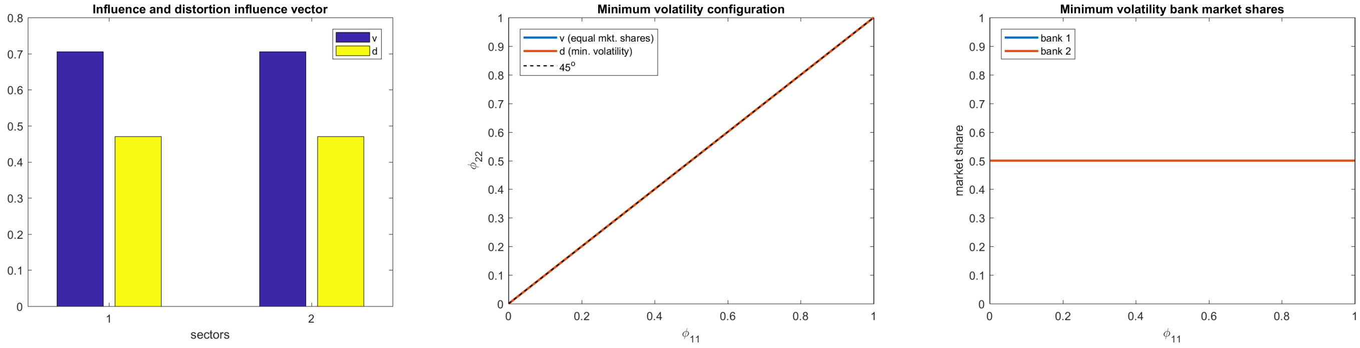
How should financial intermediation be organised in order to minimize aggregate volatility? That is, for a given input-output network, what are banks' optimal (volatility minimising) shares ϕ_{ib} in financing individual sectors, and what are the implications for the the distribution of bank market shares s_b? To gain insights towards answering these questions, consider a stylised economy with $n = 2$ sectors and $m = 2$ banks. We set $\eta = 0.85$, $\alpha = 0.71$ and $\xi = 0.20$; these parameter values conform with our baseline calibration obtained in Section 5.4.2 below and imply a binding borrowing constraint as $\xi < \eta\alpha$. We also assume that the idiosyncratic cost shocks z_b have a uniform volatility $\sigma_b^2 = \sigma^2$ across banks. Since the effects of the shocks z_b are scaled by the volume D_b of banks' lending, this implies that larger banks expose the production network to potentially larger shocks. Recall also that, whenever sectors have a joint exposure to individual banks, their financial shocks are correlated.

Looking at a number of different specifications, the four panels of Figure 1 plot (i) the vectors $\mathbf{v}$

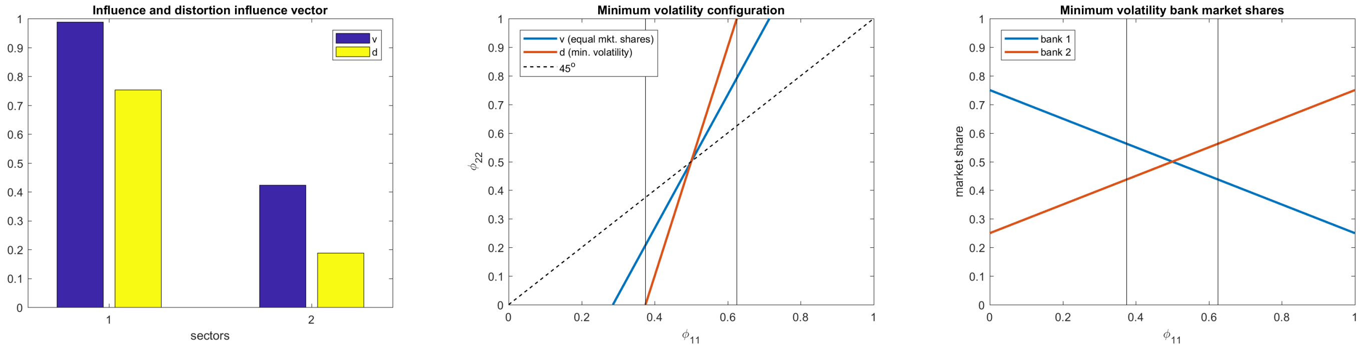
and $\mathbf{d}$ for the two sectors, (ii) the minimum volatility configuration of financial intermediation, and (iii) the associated bank market shares. For given GDP shares β and a given input-output structure $\mathbf{W}$, the *minimum volatility configuration* of financial intermediation is given by the collection $\{\phi_{ib}\}$ that minimises the expression for aggregate volatility in Proposition 3; in the context of the 2×2 economy at hand, it can be described in terms of the two coefficients (ϕ_{11}, ϕ_{22}), which allows for a convenient graphical representation.[14] The associated bank market shares can then be inferred from equation (5.20).

Indeed, the respective determination of the minimum volatility configuration of financial intermediation and the vector of bank market shares highlights a general property. As seen from (5.20), bank market shares are calculated based on the influence vector $\mathbf{v}$, which mirrors sectors' importance in terms of intermediate input flows. What matters for aggregate volatility, however, is not the influence vector $\mathbf{v}$ but the distortion influence vector $\mathbf{d}$, which additionally captures the extent of inefficiency (that is, the wedge between the actual and the efficient scale of production) originating at the sector level. Specifically, the approximation of δ_i in Proposition 3 makes clear that the difference vector δ traces the role of individual sectors as a source of distortions generated within the whole input-output network. In consequence, minimising the Herfindahl index of bank market shares will minimise the variance of final output whenever the distortion influence vector coincides with the influence vector, $\mathbf{d} = \mathbf{v}$. But when the two vectors differ, the minimum volatility configuration of financial intermediation will generally not entail or require the minimisation of the Herfindahl index. Figure 1 illustrates this for the simple 2×2 economy described above.

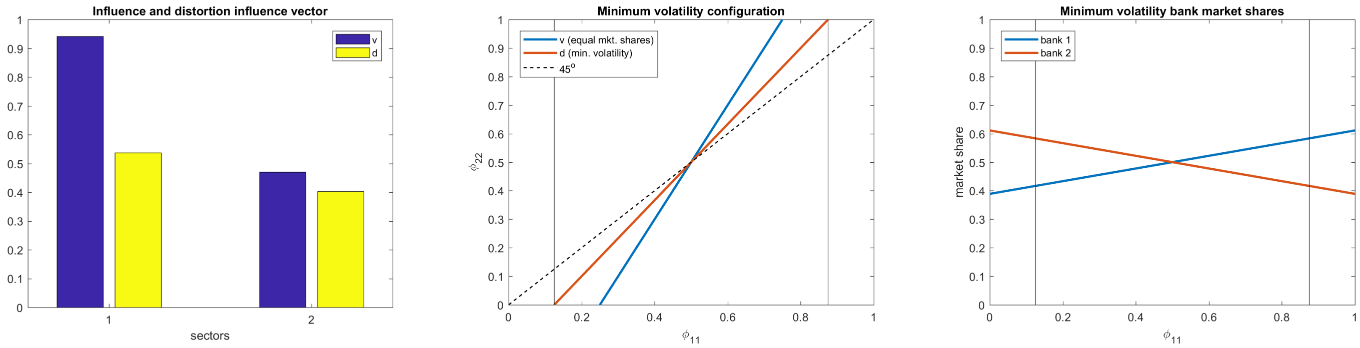
[14] Appendix C.1.7 provides the underlying analytical results for the characterisation of the minimum volatility collection $\{\phi_{ib}\}$.



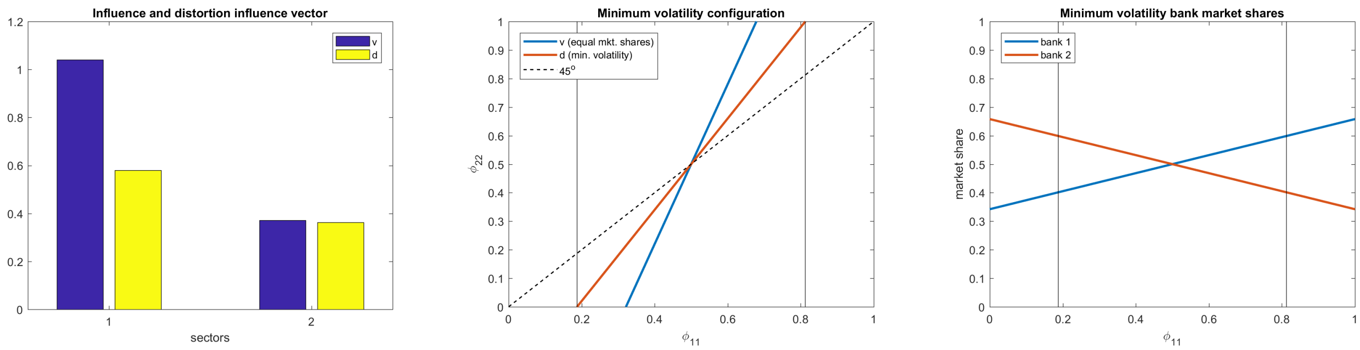
(a) $\beta' = [0.5, 0.5]$, $\mathbf{W} = [0.5, 0.5; 0.5, 0.5]$



(b) $\beta' = [0.9, 0.1]$, $\mathbf{W} = [0.5, 0.5; 0.5, 0.5]$



(c) $\beta' = [0.5, 0.5]$, $\mathbf{W} = [1, 0; 0.5, 0.5]$



(d) $\beta' = [0.5, 0.5]$, $\mathbf{W} = [1, 0; 0.9, 0.1]$

Figure 5.2: Minimum volatility configuration of financial intermediation. Vertical lines indicate the domain for ϕ_{11} compatible with minimum volatility.

Panel (a) of Figure 1 considers the symmetric economy where both sectors have identical GDP shares and are equally important as suppliers of intermediate inputs. The top middle chart shows that the minimum volatility configuration of financial intermediation is then given by all combinations of $(\phi_{11}, \phi_{22}) \in [0,1]^2$ such that $\phi_{22} = \phi_{11}$. Common to all these combinations is that they imply equal bank market shares $s_1 = s_2 = 0.5$ (see top right chart) and therefore also minimize the bank Herfindahl index. This happens in spite of a binding borrowing constraint ($\zeta > \eta$). The reason lies in the complete symmetry of the specification in panel (a). Although $\mathbf{d} \neq \mathbf{v}$, the individual entries in the two vectors are actually identical across sectors (see top left chart) so that the difference has no further implications.

Panel (b) introduces asymmetry via the vector $\beta' = [0.9, 0.1]$ of GDP shares but maintains a balanced input-output matrix $\mathbf{W}$. The middle chart again plots the minimum volatility relationship between ϕ_{11} and ϕ_{22}; the admissible domain for ϕ_{11} compatible with minimum volatility is now given by $\phi_{11} \in [0.3750, 0.6250]$. The minimum volatility relationship (red line) implies that as ϕ_{11} increases, ϕ_{22} rises with a slope larger than one.[15] That is, when bank 1 expands its lending share to the larger sector 1, bank 2 must expand its lending share to the smaller sector 2 more than proportionately. This happens for two reasons: First, to prevent the amount of credit intermediated by the two banks from diverging too strongly; and second, to compensate for the correlation of financial shocks across sectors, which is governed by the profile of *bank outdegrees*, $o_b = \sum_{i=1}^{n} \phi_{ib}$. The second motive actually implies that minimum volatility rebalancing (red line) is more pronounced than what would be required to retain equal bank market shares (blue line), to the extent that the principal financier of sector 1 ends up with a lower outdegree. To understand the underlying logic, recall the expression for aggregate volatility in Proposition 3 and observe from the left chart in panel (b) that, in the present example, the difference vector is constant across sectors, $\delta_1 = \delta_2 = \delta < 0$. The volatility

[15]Formally, the minimum volatility relationship is given by $\phi_{22} = \frac{d_1}{d_2}\phi_{11} - \frac{d_1 - d_2}{2d_2}$ subject to $\frac{d_1 - d_2}{2d_1} \leq \phi_{11} \leq \frac{d_1 + d_2}{2d_1}$.

formula then implies

$$var[\ln Y] = \sigma^2\eta^2 \sum_{b=1}^{m} \left(\left(\frac{\alpha}{1-\zeta(1-\alpha)} \right) s_b + \delta o_b \right)^2 .$$

Accordingly, as $\delta < 0$, the minimum volatility configuration assigns a low market share s_b to banks with a small outdegree o_b. As seen from the right chart, the consequence is that the bank with the larger funding share ϕ_{1b} for the important sector 1 should have a smaller overall lending volume D_b and hence a market share $s_b < 0.5$.

Panel (c) breaks symmetry in the other dimension by considering an input-output matrix $\mathbf{W}$ with a supply chain structure where sector 2 relies on intermediate inputs from both sectors while sector 1 produces without external intermediate inputs. That is, asymmetry is now generated not via sectoral GDP shares but via the input-output network; the left chart demonstrates that the difference vector then becomes unbalanced, $\delta_1 < \delta_2 < 0$. The minimum volatility relationship between ϕ_{11} and ϕ_{22} (red line) again displays a slope larger than one, but in contrast to the previous example it is now flatter than the equal market shares relationship (blue line). This is because the minimum volatility configuration assigns a larger market share $s_b > 0.5$ to the principal financier of the high-influence sector 1, here bank 1. The minimum volatility configuration thus displays tolerance towards the size of banks that are important for funding important, high-influence sectors.

Finally, panel (d) considers a variation of the example considered in panel (c), which further amplifies the asymmetry in intermediate input flows. In line with its increased dominance as a supplier of intermediate goods, an increased funding contribution to sector 1 is now assessed with an extra amount of tolerance for market share expansion. Compared to panel (c), the admissible interval for ϕ_{11} compatible with minimum volatility is centered more tightly around 0.5, but the range of the distribution of tolerated market shares is now wider.

In sum, the preceding set of examples illustrates that, in an (asymmetric) inefficient economy, the minimum volatility configuration of financial intermediation is compatible with a non-degenerate distribution of bank market shares. The expression for bank market shares in (5.20) illustrates that banks lending to high-influence sectors tend to be large. Looking at the minimum volatility configuration, whether asymmetry amplifies or mitigates this natural effect depends on the particular source of heterogeneity across sectors: An increased funding share for high-β sectors implies that the bank's market share should shrink (see panel (b)). By contrast, an increased funding share for sectors that play a dominant role as input suppliers implies that the bank's market share should expand (see panels (c) and (d)).

5.4 Empirical illustration

In this Section, we provide an empirical illustration of the implications of the theory developed so far. The application is to the Ugandan economy. In view of the importance of financial frictions and the institutional environment for financial intermediation, we see Uganda as particularly suitable for this purpose. As detailed in Appendix C.2.1, the formal economy in Uganda displays a pronounced bank dependence with few alternative means of finance available to firms; on average, 96 per cent of private credit comes from banks. The banking sector itself relies strongly on funding via deposits and the interbank market is weak; these features are consistent with the formalisation of credit supply shocks developed in our theory. Finally, with a 3-bank (5-bank) concentration ratio in 2017 of more than 40 per cent (60 per cent), the Ugandan banking industry – comprised of 25 banks – is characterised by a high degree of concentration.

The expression for aggregate volatility established in Proposition 3 is used to link the theoretical and empirical parts of this chapter. This proposition 3 is rewritten into three terms, the first term provides the Herfindahl index of bank market shares, the second term captures the interaction between the Herfindahl index and the extra distortion term and the last(outdegree correction) term represents the aggregate contribution of shocks in the banking system. In the application of this proposition we first address the question whether the relationship between financial intermediation and macroeconomic outcomes is due to concentration in the banking industry or concentration on the economy's production side. We show through the prism of the decomposition result, aggregate volatility is driven by the Herfindahl term and the outdegree correction term. And finally proposition 3 is used to quantify the empirical contribution of idiosyncratic credit supply shocks to the volatility of GDP in Uganda.

We proceed in three steps. First, Section 5.4.1 provides an empirical estimate of the magnitude of bank-level credit supply shocks and their consequences for credit dynamics at the bank and sector level. Second, Section 5.4.2 describes the structure of the intermediation and production networks in detail and calibrates the model to the environment observed in Uganda. Third, Sections 5.4.3 and 5.4.4 employ the calibrated economy to undertake a number of counterfactual experiments focused on (i) the decomposition of the sources of aggregate volatility and (ii) the degree of amplification in the mapping from idiosyncratic shocks to aggregate outcomes.

5.4.1 Credit supply shocks

Data. Our empirical assessment of credit supply shocks in the Ugandan banking sector builds on data obtained from the Bank of Uganda (BoU), the national central bank which is also responsible for the supervision of the banking sector in Uganda. We use loan-level data on credit in the domestic banking system compiled by Compuscan, a credit reference bureau, for the Bank of Uganda. Compuscan maintains the credit register under the supervision of the Bank of Uganda. Covering the entire banking system in Uganda, it provides monthly data on firm borrowing for the period from January 2012 to June 2020. Data used covers the period when the credit reference bureau produced a clean, consistent and most recent run of data.

The credit register data records the parties involved in each loan and thus allows for the classification of loans according to identifiable bank-firm pairs. We eliminate the two smallest banks from our data set as their lending is driven by special considerations and quantitatively insignificant, accounting for a negligible share of overall bank credit. This leaves us with 23 banks, whose lending activity accounts for the bulk of private-sector lending in Uganda.

While the data is in principle available at the firm-level, compliance with the BoU's confidentiality standards forces us to aggregate data at the level of industrial sectors – the level of aggregation also relevant to our theoretical model. Hence, the primary data at the bank-firm level are collapsed into loan series at the sector-level according to the International Standard Industrial Classification (ISIC) codes used by the Ugandan Bureau of Statistics and the central bank. In detail, the ten broad sectors are: Agriculture, Forestry and Fishing; Business; Building; Electricity and Water; Manufacturing; Mining and Quarrying; Social; Trade; Transport; Others.[16] We then consolidate the monthly bank-sector level series into quarterly and annual loan aggregates, computed as the total volume of credit provided by a lender (bank) to a particular sector over the quarter or year, respectively. At quarterly frequency, this produces a data set of 6881 bank-sector observations, where the lending relationship lasts more than one quarter. For the annual data, we end up with 1535 bank-sector observations with credit relationships over more than one year.

Methodology and results. A key challenge for empirical work on banking is to isolate changes in loan supply from changes in loan demand. This leads Khwaja and Mian (2008) to argue that the assessment of how shocks to the banking system affect the real economy must simultaneously confront two separate channels: the *bank lending channel* and the *firm borrowing channel*. The bank lending channel rests on bank's inability to insulate borrowing firms from bank-specific liquidity shocks, while the firm borrowing channel is due to firms' inability to compensate bank lending shocks by substituting towards alternative sources of financing.

[16]Table 2 below provides the mapping of ISIC codes into these broad sectors as well as their GDP shares.

We examine the bank lending and firm borrowing channels in Uganda, following ideas in Amiti and Weinstein (2018b) and Alfaro, García-Santana and Moral-Benito (2020). In line with our theoretical model, our approach exploits linked bank-sector data so that the unit of observation is given by x_{ib}, that is, the volume of loans from bank b to sector i. Specifically, our identification of supply and demand shocks to the growth of bank credit exploits the fact that each bank lends to multiple sectors, and each sector borrows from multiple banks.

To start, consider the following decomposition of credit growth between bank b and sector i at time t,

$$\Delta \ln(x_{ibt}) = \varsigma_{bt} + \delta_{it} + \epsilon_{ibt}, \tag{5.21}$$

where x_{ibt} denotes the average of outstanding loans from bank b to firm i over period t; ς_{bt} is a bank-time fixed effect, and δ_{it} is a firm-time fixed effect. The fixed effects in (5.21) can be interpreted as supply and demand shocks, respectively. In particular, ς_{bt} captures idiosyncratic shocks to bank b which are identified through differences in credit growth across banks lending to the same sector: From observing a sector whose credit from bank b displays stronger growth than that from bank b', we conclude that bank b was subject to a more favourable supply shock than bank b'. The identification of the demand shocks δ_{it} follows a similar logic. Finally, ϵ_{ibt} captures other shocks to the bank-firm relationship assumed to be orthogonal to the bank and firm effects.[17]

We find no evidence indicating a systematic effect of bank size on volatility (see Appendix C.2.2 for a scatter plot). A linear regression of bank volatility on size results in a slope estimate of -0.01 estimated without significance ($p = 0.28$). Our subsequent analysis will thus assume a uniform volatility at the level of the cross-sectional average, $\sigma_b = \sigma = 0.3313$.

[17] Amiti and Weinstein (2018b) show that the bank-time and sector-time fixed effects estimated on the basis of (5.21) are identical to those obtained from a specification that also allows for bank-sector-time effects Z_{ibt}. The key insight is that one can always express the interaction term as $Z_{ibt} = \varsigma_{bt} + \delta_{it} + \zeta_{ibt}$, where ζ_{ibt} is an error term. It is therefore possible to define the bank and sector shocks such that they are invariant to the inclusion of the interaction term, and they can be consistently estimated from equation (5.21).

In order to quantify the magnitude of the bank lending channel, we estimate the following model,

$$\Delta \ln(x_{ibt}) = \beta^b \hat{\varsigma_{bt}} + \eta_{it} + \nu_{ibt}, \tag{5.22}$$

where $\hat{\varsigma_{bt}}$ is the bank-specific credit supply shock estimated in (5.21) and then normalised to have zero mean and unit variance. The sector-time fixed effect η_{it} controls for time-varying demand shocks, which is feasible due to banks' credit exposure to multiple sectors. The magnitude of the bank lending channel is then captured by parameter β^b; given the normalisation of $\hat{\varsigma_{bt}}$, the estimate can be interpreted in terms of the change in the gross rate of credit growth induced by a one-standard deviation bank-specific shock to credit supply.

Table 1 reports our results. The first column examines the bank lending channel at the bank-

	quarterly credit growth	annual credit growth
credit supply shock	0.331***	0.532***
	(369.11)	(256.90)
obs	6881	1535
$adj.R^2$	0.169	0.245

Heteroskedasticity robust standard errors clustered at the bank level; t statistics in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 5.1: Bank lending channel

sector level at quarterly frequency and identifies a positive and significant effect. Conditional on sector-time fixed effects, increased credit supply from a given bank implies higher credit growth for sectors with a credit relationship to that bank. The magnitude of this effect is substantial: A one standard deviation increase in credit supply leads to an increase in the growth rate of bank-sector credit by 0.33 percentage points; this is relative to an average growth rate of credit of 2.67 per cent. The second column repeats the exercise at annual frequency.[18] Bank credit supply shocks are again associated with positive effects on credit growth. For sectors with an existing

[18] Working with annual data implies having more sector observations per bank, allowing for a better estimation of bank credit supply shocks. On the other hand, though, with quarterly data sector-time effects can vary within a year, which facilitates a better control for demand shocks.

credit relationship to a particular bank, bank-specific credit supply shocks are estimated to result in an increase in credit growth by 0.53 percentage points relative to an average growth rate of 8.08 per cent. We conclude that credit supply shocks have statistically and economically important effects on bank-sector credit growth. When comparing the estimates at quarterly and annual frequency, notice that, even though the shocks have a smaller absolute effect for the quarterly data, their magnitude relative to the underlying average growth rates is actually larger. This points to the fact that borrowers are able to partially offset the effect credit supply shocks over time. Indeed, borrowing firms or sectors may still be able to insulate themselves from idiosyncratic bank credit supply shocks by resorting to credit from alternative sources, and in particular from other banks.

In a second step, we seek to examine to what extent a negative bank lending shock actually translates into a reduction of available credit for borrowers. To that end, we use the idiosyncratic credit supply shocks $\hat{\varsigma}_{bt}$ identified in (5.21) to construct a measure of credit availability at the sector level. Specifically, we again start from the normalised version of $\hat{\varsigma}_{bt}$ and compute the credit supply shock facing a particular sector as the weighted average of the idiosyncratic supply shocks across the banks with an existing credit relationship to the sector,

$$\bar{\varsigma}_{it} = \sum_{b} \frac{x_{ibt-1}}{\sum_b x_{ibt-1}} \hat{\varsigma}_{bt}. \tag{5.23}$$

Next, we regress sectors' credit growth on the constructed credit supply measure and the idiosyncratic demand shocks $\hat{\delta}_{it}$ (again normalised to have zero mean and unit variance) from (5.21),

$$\Delta \ln(x_{it}) = \beta^i \bar{\varsigma}_{it} + \gamma \hat{\delta}_{it} + u_{it}. \tag{5.24}$$

Similar to the bank lending channel estimated in (5.22), the magnitude of the sector borrowing channel is reflected in parameter β^i.

Table 2 provides our estimates, contrasting effects at quarterly and annual frequency. The first

	quarterly credit growth	annual credit growth
credit supply shock	1.090***	1.583***
	(7.67)	(6.09)
obs	5919	1361
$adj.R^2$	0.069	0.073

Heteroskedasticity robust standard errors clustered at the bank level; t statistics in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 5.2: Sector borrowing channel

column examines the sector borrowing channel based on quarterly data. Our estimate implies that, controlling for credit demand, a one-standard deviation shock in the overall credit supply available to a given sector leads to an increase in the growth of the sector's bank credit by 1.09 percentage points. Revisiting the credit dynamics induced by credit supply shocks at annual frequency, the second column reports an even larger borrowing channel estimate of 1.58 percentage points. Hence, consistent with our theoretical model, there is a quantitatively relevant pass-through of idiosyncratic credit supply shocks to observed credit growth at the sector level. Interestingly, the estimated effects are even larger in magnitude than their counterparts from Table 1 ($\beta^i > \beta^b$).

5.4.2 Production and intermediation networks

Building on the empirical estimates, we now examine the consequences of idiosyncratic credit supply shocks within our model economy when it is calibrated to network data from Uganda. The key primitives of our model economy are the input-output matrix $\mathbf{W}$ and the intermediation matrix $\mathbf{\Phi}$. Data for the construction of $\mathbf{W}$ come from the Eora Global Supply Chain Database (Lenzen, Moran, Kanemoto and Geschke, 2013) which provides the input-output table across 26 industrial sectors in Uganda for the year 2015.[19] Consistency with the loan information described in Section 5.4.1 requires that we aggregate the 26 original sectors into 10 broad

[19]The Eora Global Supply Chain Database is available at `https://worldmrio.com/`.

sectors as detailed in Table 2 below along with sectors' ISIC codes and GDP shares β.

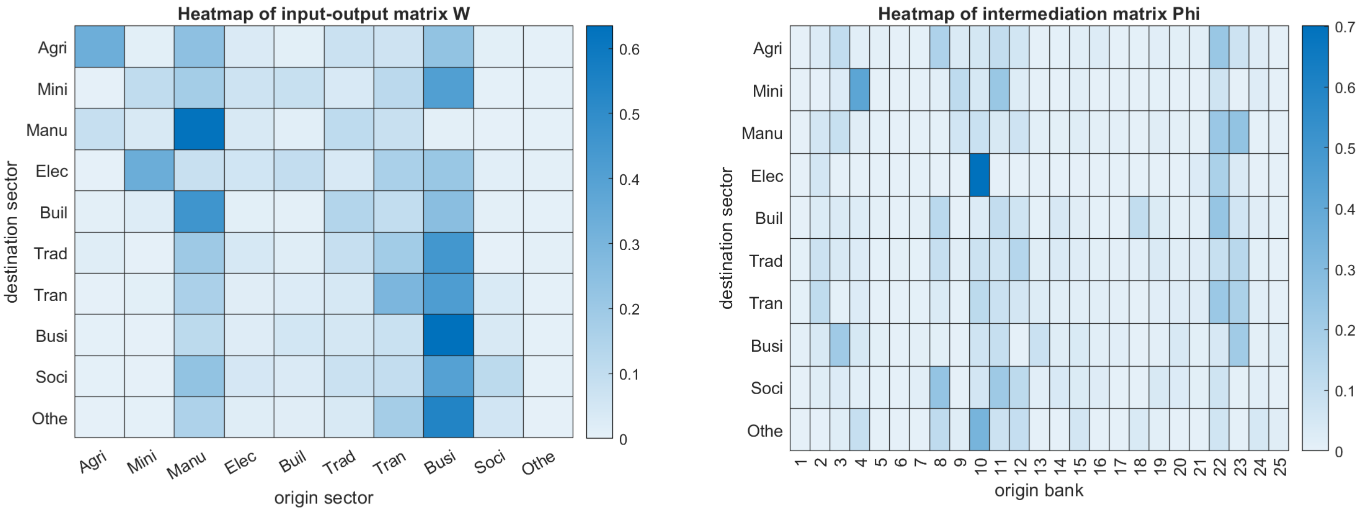
Sector	ISIC	GDP share β
Agriculture, Forestry and Fishing	A	0.2639
Mining and Quarrying	B	0.0098
Manufacturing	C	0.1768
Electricity and Water	D + E	0.0384
Building	F + L	0.1216
Trade	G + I	0.1331
Transport	H + J	0.0525
Business	K + M + N	0.0793
Social	P + Q + R	0.0857
Others	S + T	0.0389

GDP shares from Uganda Bureau of Statistics and authors computations.

Table 5.3: Industrial sectors

We obtain the coefficients ω_{ij} by dividing the empirically observed input flow from industry j to industry i by the sum of all input flows to industry i. The intermediation matrix $\mathbf{\Phi}$ is constructed in the same fashion based on data obtained from Compuscan (see Section 5.4.1); as for $\mathbf{W}$, we again exploit data for the year 2015. Specifically, the coefficients ϕ_{ib} are derived by dividing the empirically observed volume of loans originated by bank b to industry i by the overall volume of loans to industry i. Figure 2 below presents heatmaps for the input-output matrix $\mathbf{W}$ and the intermediation matrix $\mathbf{\Phi}$, respectively. The input flows summarised in panel (a) show relatively strong entries along the main diagonal, indicating that the mix of industrial sectors' intermediate inputs assigns an important role for inputs originating within the same sector. Moreover, three sectors stand out as important suppliers of inputs: Manufacturing, Transport and Business. Similarly, the loan flows mapped in panel (b) reveal the dominance of individual banks (e.g., bank 10 and bank 22) in financing the production in many industrial sectors; these are banks with a high bank outdegree, $o_b = \sum_{i=1}^{n} \phi_{ib}$. Moreover, there is substantial heterogeneity in sectoral loan exposures across banks.[20] In sum, both matrices $\mathbf{W}$ and $\mathbf{\Phi}$ are characterised by a fair amount of asymmetry.

[20]Examining repeated snapshots of the data, we find this heterogeneity to be persistent, consistent with the idea of specialisation in bank lending. We take this as evidence of relationship lending where expertise and relationship capital are built up within bank-sector pairs. There is thus only limited substitutability across bank loans originated by different banks, and shocks affecting a bank's lending capacity can be expected to have real effects on their borrowers.



(a) Input-output flows (2015)

(b) Loan flows (2015)

Figure 5.3: Heatmaps for input-output matrix $\mathbf{W}$ and intermediation matrix $\mathbf{\Phi}$.

To complete the parameterisation of the model, the degree of decreasing returns to scale η, the Cobb-Douglas share for the labor input α and the tightness of the borrowing constraint ξ must be calibrated. While ξ can be pinned down from information in the input-output table, the parameters η and α cannot be determined directly. This reflects the fundamental problem of separately identifying differences in distortions from differences in technology (cf. Jones, 2013). We therefore proceed as follows. The input-output table provides information not only on intermediate input flows but also on the compensation of primary factors, including the compensation of employees. For each sector i, we can thus break down overall expenditure into the aggregate intermediate input component across all industries $\sum_{j=1}^{n} p_j q_{ij}$ and the compensation of primary factors, which, among other things, includes the wage bill $w\ell_i$ as a separate item. Calculating the respective expenditure shares and averaging across sectors, we thus obtain statistics for the intermediate expenditure share and the wage bill relative to sales revenue; they are given by $\zeta(1-\alpha) = 0.31$ and $\xi = 0.20$.[21]

[21] Jones (2013) argues that the intermediate goods share of gross output is about 0.5 across a large number of countries (see his Table 3). Compared to that, our measure of $\zeta(1-\alpha) = 0.31$ under the 10-sector dis

We set the returns-to-scale parameter at $\eta = 0.85$ as in Restuccia and Rogerson (2008); conditional on this value for η and a guess for α, we can compute $\zeta = \frac{1-\xi}{1-\eta\alpha}\eta$ and thus obtain an implied value for the intermediate good share $\zeta(1-\alpha)$; iterating on the guess for α to hit the target $\zeta(1-\alpha) = 0.31$ then delivers $\alpha = 0.89$ and $\zeta = 2.78$. In view of the fundamental identification problem surrounding η and α, we also explore the robustness of our results under different values for η.[22] Table 3 below summarises the outcomes of our calibration exercise when η ranges in the interval $[0.7, 1)$.

$\zeta(1-\alpha) = 0.31$	$\eta = 0.7$	$\eta = 0.8$	$\eta = 0.85$	$\eta = 0.9$	$\eta = 0.99$
α	0.7289	0.8418	0.8884	0.9297	0.9936
ζ	1.1433	1.9600	2.7767	4.4100	48.5100
$\chi\alpha + \zeta(1-\alpha)$	0.5100	0.5100	0.5100	0.5100	0.5100
$\frac{\alpha}{1-\zeta(1-\alpha)}$	1.0563	1.2201	1.2875	1.3474	1.4400
$\zeta(1-\alpha) = 0.50$	$\eta = 0.7$	$\eta = 0.8$	$\eta = 0.85$	$\eta = 0.9$	$\eta = 0.99$
α	0.2857	0.5833	0.7059	0.8148	0.9832
ζ	0.7000	1.2000	1.7000	2.7000	29.7000
$\chi\alpha + \zeta(1-\alpha)$	0.7000	0.7000	0.7000	0.7000	0.7000
$\frac{\alpha}{1-\zeta(1-\alpha)}$	0.5714	1.1667	1.4118	1.6296	1.9663

Table 5.4: Baseline calibration and sensitivity to η

The top panel considers the 10-sector disaggregation where $\zeta(1-\alpha) = 0.31$. As seen, the effects are monotonic in the degree of decreasing returns: The higher η, the higher α and ζ. By contrast, there is no effect on the ratio of total expenditure relative to sales revenue, which is always given by $\chi\alpha + \zeta(1-\alpha) = 0.51$. In addition, the fraction $1-\eta$ can be interpreted as the share of sales revenue accrued to fixed factors like physical capital and land. Consistent with the importance of financial constraints, which inefficiently restrain the scale of business operation, firms are thus fairly profitable. In consequence, profit leakage plays a quantitatively important role. Indeed, the multiplier $\sum_{i=1}^{n} v_i = \frac{\alpha}{1-\zeta(1-\alpha)}$ rises from about 1.05 when $\eta = 0.7$ (high profit leakage) to about 1.44 when $\eta = 0.99$ (low profit leakage). Nevertheless, the multiplier throughout exceeds one because the input substitution effect from labour towards intermediate goods dominates the effect of decreasing returns.

aggregation is lower. Reverting to the original, finer 26-sector dis aggregation results in an intermediate goods share of 0.50.

[22]Bigio and La'O (2020) take a similar approach.

Although the intermediation matrix $\mathbf{\Phi}$ is based on a dis-aggregation into $n = 10$ broad industrial sectors, the EORA data on the input-output network $\mathbf{W}$ are available at a finer resolution with $n = 26$ sectors. The bottom panel of Table 3 therefore considers the finer 26-sector dis aggregation, which results in a higher intermediate goods share of $\zeta(1-\alpha) = 0.50$; the working capital parameter remains basically unchanged at $\xi = 0.20$. Qualitatively, the results are similar to the previous specification, but they display greater sensitivity to η. Overall, the implied parameterisation appears more plausible with an overall expenditure share for labour and intermediate inputs of 0.70 and a Cobb-Douglas parameter of $\alpha = 0.71$ when $\eta = 0.85$. Moreover, in view of the lower labor share α, it is also more conservative with respect to the implied scale distortion of firms' production (cf. Lemma 2). The multiplier $\frac{\alpha}{1-\zeta(1-\alpha)}$ now ranges from about 0.57 when $\eta = 0.7$ to about 1.97 when $\eta = 0.99$.[23] Since the dis-aggregation into $n = 26$ industrial sectors arguably delivers a more accurate picture of the role of intersectoral input-output linkages, we will work with this as our baseline calibration.

Figure 3 examines the properties of key objects summarising the sectoral and banking composition of the calibrated economy. Beginning with the production network, panel (a) displays the influence vector $\mathbf{v}$ and the distortion influence vector $\mathbf{d}$. The underlying heterogeneity in sectors' size and their role for the input-output flows is visible for both vectors, which highlight the network importance of the Agriculture, Manufacturing and Business sectors. At the same time, however, there are non-trivial differences between the two vectors, reflecting the divergence between sectors' fundamental role for the flow of intermediate inputs and their importance for the transmission of credit supply shocks within the production network.

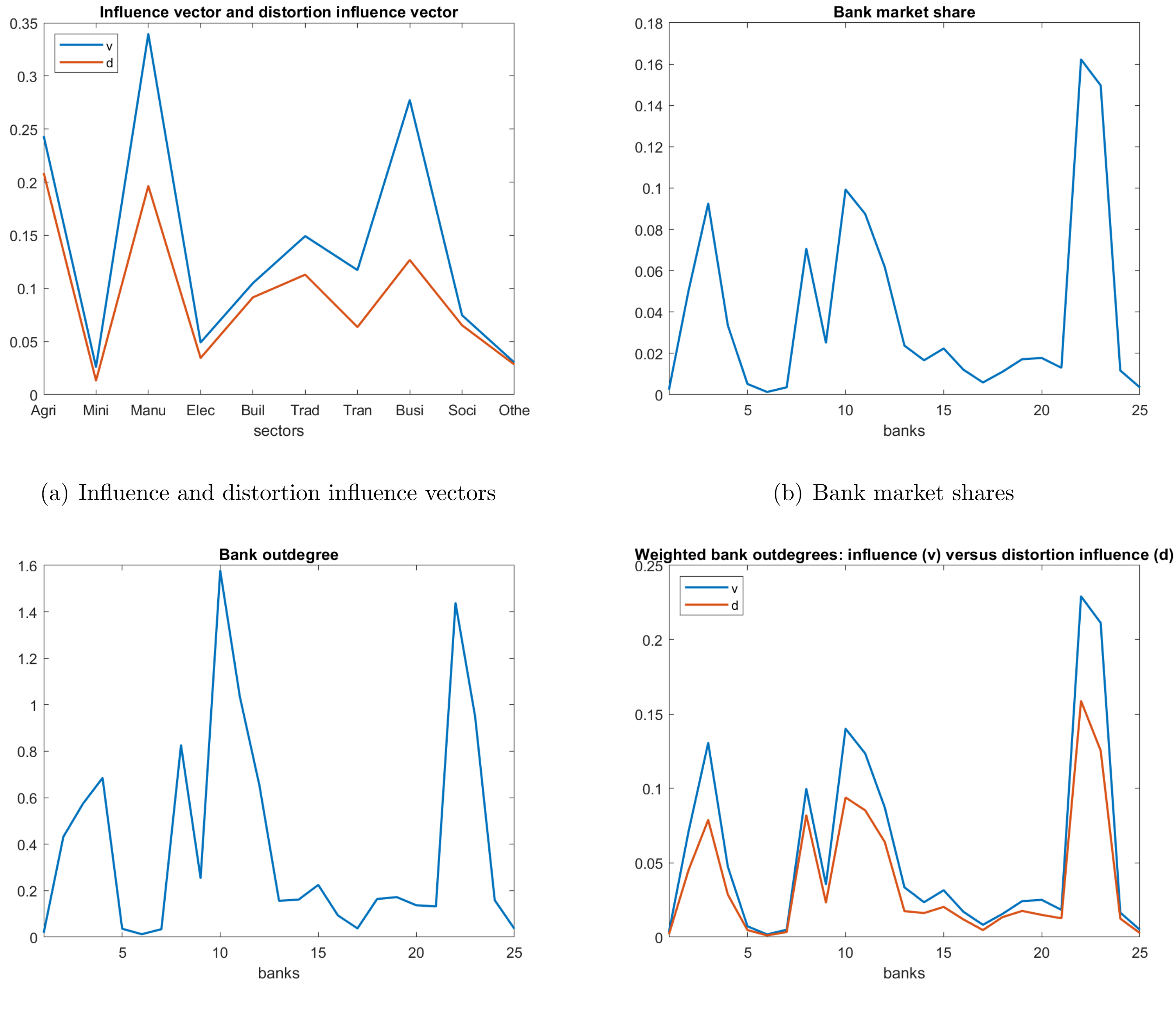
Turning to financial intermediation, panel (b) shows the composition of the banking industry as measured by individual banks' market shares s_b. The top 5 banks command a cumulative market share of about 60 per cent, and the bank Herfindahl index is given by $\sum_b s_b^2 = 0.0905$.

[23] When $\eta = 0.7$, the borrowing constraint is just binding ($\xi < \eta\alpha \approx 0.2$). There is almost no input substitution ($\eta < \zeta \approx 0.7$), and the profit leakage induced by decreasing returns implies that the multiplier is smaller than one.

Panel (c), in turn, plots the profile bank outdegrees $o_b = \sum_{i=1}^{n} \phi_{ib}$, which generally resembles that of the bank market shares, although there are some differences as the bank outdegree does not take account of the overall loan volume going to individual borrowing sectors.

This is addressed in panel (d), which depicts two weighted bank outdegree vectors, where the weights are given by $\mathbf{v}$ and $\mathbf{d}$, respectively. When weighted with the sectoral influence vector, the weighted outdegree vector $\sum_{i=1}^{n} v_i \phi_{ib}$ actually corresponds to the vector of market shares up to a scaling term.[24] When weighing with the distortion influence vector instead, the alternative weighted outdegree vector $\sum_{i=1}^{n} d_i \phi_{ib}$ gives a slightly different picture. As seen in Proposition 3, it is the latter vector that determines the economy's level of aggregate volatility, and its divergence from the former vector gives rise to the outdegree correction term characterised there.

[24] See (C.1.10) in Appendix C.1.4.



(a) Influence and distortion influence vectors

(b) Bank market shares

(c) Bank outdegrees

(d) Weighted bank outdegrees

Figure 5.4: Intermediation statistics.

5.4.3 Decomposition

An important question concerning the relationship between financial intermediation and macroeconomic outcomes is whether concentration in the banking industry matters in itself or whether it is merely a reflection of concentration on the economy's production side. For example, Bremus et al. (2018, p. 32) observe that the effects of granularity in banking identified in their empirical work '*might, in fact, be merely manifesting granular effects from the manufacturing sector. If large banks and large firms are linked financially, then our effects might pick up large firm effects in general.*' Here, we address this question through the lens of the decomposition result in Proposition 3, which traces aggregate volatility back to two determinants, the Herfindahl term and the outdegree correction term.

As the definition of s_b in (5.20) makes clear, bank market shares arise exclusively from lending to firms, whereby large banks emerge as the consequence of lending to important (high v_i) sectors. The resulting volatility effects are captured via the Herfindahl term in Proposition 3. By contrast, the outdegree correction term term arises as a consequence of the divergence between sectors' influence v_i and distortion influence d_i coupled with banks' lending exposure to these sectors. As seen in Proposition 3, this term becomes relevant independent from bank concentration.

Exploiting the binomial structure of these two terms, another way to write the expression for aggregate volatility established in Proposition 3 is

$$var[\ln Y] = \sigma^2 \eta^2 \sum_{b=1}^{m} \left(\left(\frac{\alpha}{1-\zeta(1-\alpha)} \right)^2 s_b^2 + 2 \frac{\alpha}{1-\zeta(1-\alpha)} s_b \sum_{i=1}^{n} \delta_i \phi_{ib} + \left(\sum_{i=1}^{n} \delta_i \phi_{ib} \right)^2 \right). \tag{5.25}$$

The three constituent terms have the following interpretation. The first term, $\sum_{b=1}^{m} \left(\frac{\alpha}{1-\zeta(1-\alpha)} \right)^2 s_b^2$, gives the contribution of the familiar Herfindahl index of bank market shares already discussed above. The last term, $\sum_{b=1}^{m} \left(\sum_{i=1}^{n} \delta_i \phi_{ib} \right)^2$, represents the sum of squared bank outdegree corrections and captures the aggregate contribution of shocks in the banking system, insofar as they lead to distortions that matter independently from what is already accounted for via bank size. This extra distortion term arises because, under financial frictions, firms operate at a lower scale as measured by their total expenditure share. Given the curvature in (5.1), this implies that fluctuations in factor use translate into larger fluctuations in output and hence in higher volatility. Finally, the middle term , $\sum_{b=1}^{m} 2\frac{\alpha}{1-\zeta(1-\alpha)} s_b \sum_{i=1}^{n} \delta_i \phi_{ib}$, represents the interaction between the Herfindahl term and the extra distortion term. Notice that this term is non-positive as $\delta_i \leq 0$. This reflects the fact that the Herfindahl term incorporates the increased intermediate input share $\zeta(1-\alpha)$ only but not the increased extent of profit leakage induced by the lower total expenditure share.

Table 4 details the decomposition of aggregate volatility for the two calibrations considered in Table 3, breaking it down into the three constituent terms described above (rows one to three of the respective panels). The sum of these terms, that is, the aggregate volatility factor given by the expression in parenthesis in (5.25), is presented in the fourth row ('overall'); finally, the fifth row ('volatility') denotes the aggregate volatility factor multiplied by η^2.

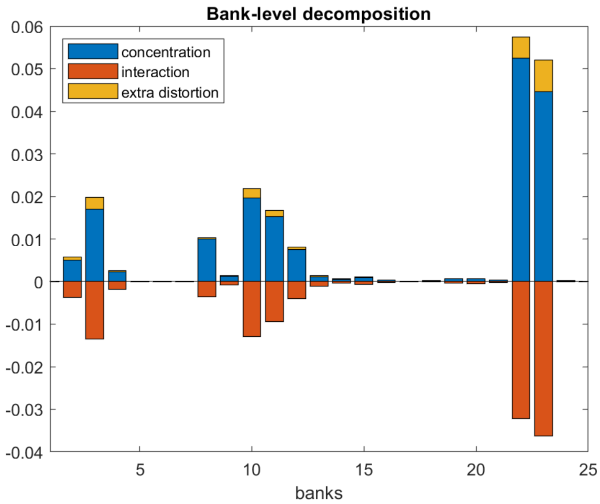
$\zeta(1-\alpha) = 0.31$	$\eta = 0.7$	$\eta = 0.8$	$\eta = 0.85$	$\eta = 0.9$	$\eta = 0.99$
concentration	0.1004	0.1339	0.1491	0.1633	0.1866
interaction	-0.0299	-0.0565	-0.0712	-0.0865	-0.1146
extra distortion	0.0024	0.0063	0.0090	0.0121	0.0186
overall	0.0728	0.0837	0.0869	0.0890	0.0906
volatility	0.0357	0.0536	0.0628	0.0721	0.0888
$\zeta(1-\alpha) = 0.50$	$\eta = 0.7$	$\eta = 0.8$	$\eta = 0.85$	$\eta = 0.9$	$\eta = 0.99$
concentration	0.0296	0.1232	0.1804	0.2404	0.3500
interaction	-0.0000	-0.0625	-0.1221	-0.1952	-0.3494
extra distortion	0.0000	0.0082	0.0213	0.0409	0.0899
overall	0.0296	0.0689	0.0797	0.0861	0.0905
volatility	0.0145	0.0441	0.0576	0.0697	0.0887

'Overall' denotes the aggregate volatility factor given by the expression in parenthesis in (5.25). 'Volatility' denotes the aggregate volatility factor multiplied by η^2.

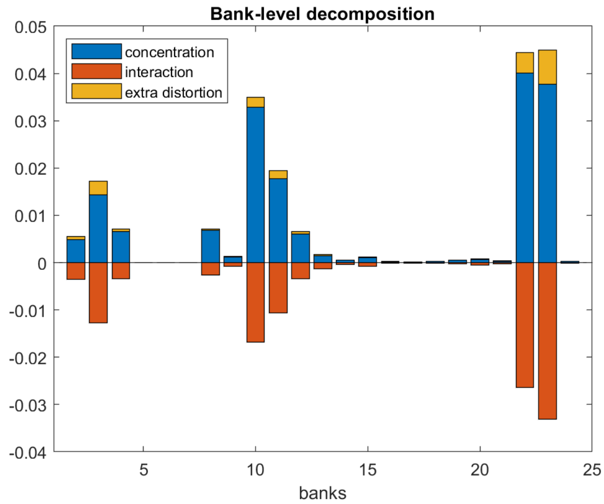
Table 5.5: Decomposition of aggregate volatility factor

Moving across the columns for the different values for the returns-to-scale parameter η, since the bank market shares s_b are given from the data, the relative behaviour of the concentration term follows that of the multiplier $\frac{\alpha}{1-\zeta(1-\alpha)}$, which is monotonically increasing in η (cf. Table 3). The same is true for the extra distortion term, which is generally smaller in magnitude but becomes more important when the intermediate goods share $\zeta(1-\alpha)$ is higher. This latter feature is evident from the definition of the difference vector in Proposition 3: The distortions induced via the input substitution mechanism described in Lemma 1 become more relevant under a higher intermediate goods share. While the concentration and extra distortion terms contribute to higher aggregate volatility, their interaction is sizeable and works in the opposite direction. Reflecting the importance of profit leakage, both the resulting aggregate volatility factor and aggregate volatility itself are increasing in η. As the production technology approaches its CRS limit of $\eta = 1$ (no profit leakage), we observe the highest aggregate volatility of almost 9 per cent.

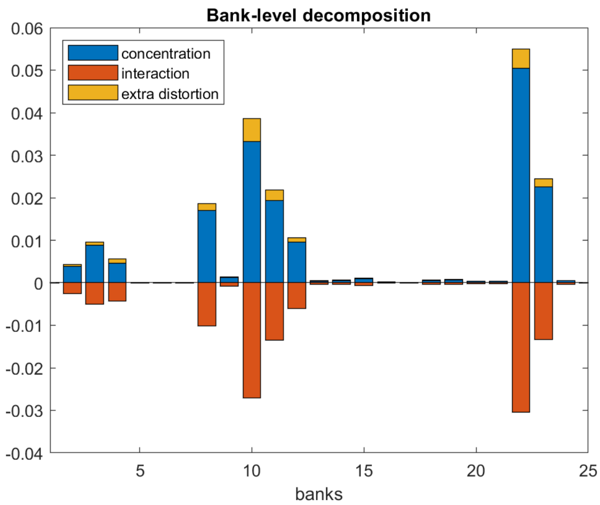
Behind these aggregate outcomes lies a profile of bank-level shocks that are transmitted first via the intermediation network $\mathbf{\Phi}$ and then via the input-output network $\mathbf{W}$. In order to understand the details of this transmission, Figure 3 looks at the bank-level contributions to aggregate volatility under the baseline calibration with $\zeta(1-\alpha) = 0.50$.



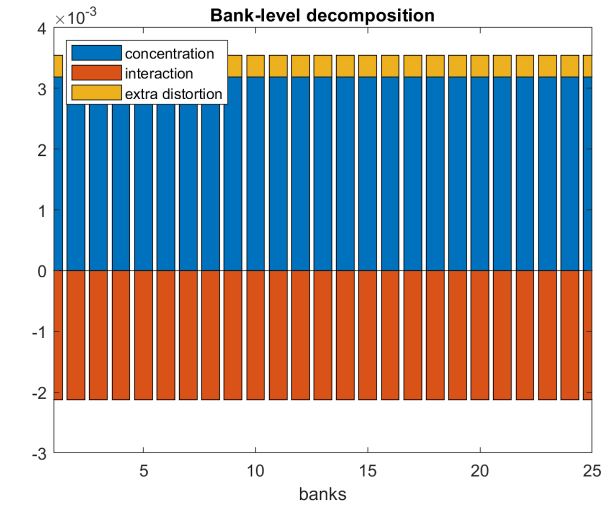
(a) Empirical data



(b) No β heterogeneity



(c) No $\mathbf{W}$ heterogeneity



(d) No $\mathbf{\Phi}$ heterogeneity

Figure 5.5: Contribution to aggregate volatility: bank-level decomposition.

As seen in panel (a), the economy with the empirically observed asymmetry in β, $\mathbf{W}$ and $\mathbf{\Phi}$ has substantial heterogeneity in (i) the contribution of individual banks to aggregate volatility, and (ii) the bank-level decomposition of this contribution into its respective components. On the one hand, this heterogeneity mirrows the differences across banks already identified in the intermediation heatmap of Figure 2 above; and on the other hand, it provides a dis-aggregate perspective at the volatility decomposition in Table 4. The other panels of Figure 3 examine the consequences for the bank-level contribution to aggregate volatility when individual sources of asymmetry are removed. Eliminating heterogeneity from the input-output network, either via β (panel (b)) or $\mathbf{W}$ (panel (c)), keeps this general pattern intact but leads to some changes in both the decomposition across and within banks. By contrast, eliminating the asymmetry in the intermediation network via the matrix $\mathbf{\Phi}$ (panel (d)) mechanically implies that the decomposition becomes identical across banks.

What are the implications for aggregate volatility? Table 5 addresses this question on the basis of the above counterfactuals.

$\zeta(1-\alpha) = 0.50$	baseline	no β	no $\mathbf{W}$	no β & no $\mathbf{W}$	no $\mathbf{\Phi}$	full symm.
concentration	0.1804	0.1737	0.1755	0.1778	0.0797	0.0797
interaction	-0.1221	-0.1176	-0.1165	-0.1185	-0.0531	-0.0531
extra distortion	0.0213	0.0209	0.0198	0.0198	0.0089	0.0089
overall	0.0797	0.0771	0.0787	0.0790	0.0354	0.0354
volatility	0.0576	0.0557	0.0569	0.0571	0.0256	0.0256
Herfindahl	0.0905	0.0871	0.0881	0.0892	0.0400	0.0400

'Overall' denotes the aggregate volatility factor given by the expression in parenthesis in (5.25). 'Volatility' denotes the aggregate volatility factor multiplied by η^2.

Table 5.6: Aggregate volatility under changing heterogeneity pattern

Compared to the baseline economy, removing asymmetry from the input-output network via sectoral GDP shares β (column two), the configuration of intermediate input flows as captured by $\mathbf{W}$ (column three) or both (column four) has only marginal effects on aggregate volatility and its decomposition. The pattern of the relevant figures reveals that, at a general level, asymmetry in the input-output network actually has mixed effects on aggregate volatility. The underlying reason is that, empirically, heterogeneity in β and $\mathbf{W}$ do not work hand in hand in that large sectors are not necessarily important as suppliers of intermediate inputs for other sectors.[25] By contrast, eliminating asymmetry in financial intermediation by imposing a uniform intermediation matrix $\mathbf{\Phi}$ implies a degenerate bank size distribution and thus minimises

[25]For example, Agriculture, Forestry and Fishing accounts for more than a quarter of GDP, but it has only a limited role as supplier of intermediate inputs to other sectors (cf. Figure 2).

the bank Herfindahl index at $25 \times 0.04^2 = 0.04$. This leads to a substantial reduction in aggregate volatility from 0.0576 to 0.0256.[26] Finally, as seen from comparing columns five and six, establishing full symmetry by eliminating all sources of heterogeneity across banks ($\mathbf{\Phi}$) and sectors (β and $\mathbf{W}$) has no detectable (to four digits) further effects. The key take away from Table 5 therefore is that, both conditional on the empirically observed intermediation matrix $\mathbf{\Phi}$ and on the uniform counterfactual, the input-output network as captured by β and $\mathbf{W}$ plays only a marginal role in the determination of aggregate volatility and its decomposition. Instead, what matters for aggregate volatility is the architecture $\mathbf{\Phi}$ of financial intermediation.

To get more detailed insights into the role of financial intermediation as a determinant of aggregate volatility, Table 6 examines the implications of a number of counterfactual experiments based on variations in borrowing and lending arrangements.[27]

$\zeta(1-\alpha) = 0.50$	baseline	low concentration	high concentration	diversification	specialisation $m = 25$	specialisation $m = 10$
concentration	0.1804	0.1161	0.3076	0.1778	0.1185	0.3080
interaction	-0.1221	-0.0776	-0.2110	-0.1185	-0.0922	-0.2275
extra distortion	0.0213	0.0132	0.0384	0.0198	0.0207	0.0492
overall	0.0797	0.0516	0.1350	0.0790	0.0470	0.1298
volatility	0.0576	0.0373	0.0975	0.0571	0.0339	0.0937
Herfindahl	0.0905	0.0582	0.1543	0.0892	0.0594	0.1546

'Overall' denotes the aggregate volatility factor given by the expression in parenthesis in (5.25). 'Volatility' denotes the aggregate volatility factor multiplied by η^2.

Table 5.7: Aggregate volatility under changing intermediation

To begin, we consider variations in the *concentration of sectors' borrowing* away from the empirically given intermediation matrix $\mathbf{\Phi}$. To that end, column two (low concentration) reduces sectors' dependence on individual banks by taking the square root of the existing funding shares ϕ_{ib} and then re-scaling them so that $\sum_b \phi_{ib} = 1$. Similarly, by taking the square of the

[26]Interestingly, despite this drop in aggregate volatility, the breakdown into its constituent factors remains remarkably stable, with concentration, interaction and extra distortion contributing about 225 per cent, -150 per cent and 25 per cent of the overall, respectively. Notice also that, although the Herfindahl index of bank concentration remains an appropriate indicator for aggregate volatility in relative terms, there is a noticeable level effect as seen from comparison of the entries under 'overall' and 'Herfindahl', respectively.

[27]Figure B.1 in Appendix C.2.3 provides the associated bank-level decomposition of aggregate volatility.

ϕ_{ib} instead, column three (high concentration) evaluates the consequences of increased sector dependence on important lenders. As seen, increased concentration of borrowing at the sector level implies a less diversified funding pool with increased exposure to idiosyncratic bank shocks, which ultimately results in increased aggregate volatility.

Second, we examine the consequences of *diversification of banks' lending* activity. Specifically, for each bank b, we redistribute the ϕ_{ib} by spreading them out equally across sectors so that their sum $\sum_i \phi_{ib}$ remains unchanged. Notice from (5.20) that, as long as there is heterogeneity in the sectoral influence vector $\mathbf{v}$, this experiment does generally not keep bank size s_b unchanged. Here it is of little consequence, though, as the bank Herfindahl index barely changes when moving from the baseline in column one to the diversified lending economy in column four. In line with this observation, we find that, compared to the baseline, diversified lending has almost no effect on aggregate volatility. This reflects the following trade-off: On the one hand, sectors' exposure to bank-level shocks becomes completely balanced, which the previous experiment has demonstrated to reduce aggregate volatility. But on the other hand, idiosyncratic shocks are now by construction spread across the whole network so that idiosyncratic shocks in effect become aggregate shocks, which undermines the benefits of diversification.

Third, the scenario of *specialisation in bank lending* has individual banks concentrate their entire lending on only one sector. With $n = 10$ sectors and $m = 25$ banks, our first experiment (column five) here assumes that two banks each concentrate their lending on one sector, and the five sectors with the highest GDP shares β_i obtain funding from three banks.This counterfactual is at the opposite end of the above diversification experiment and hence results in lower aggregate volatility. Notice in particular that the specialisation scenario eliminates the correlation of credit supply shocks across sectors so that the the intermediation network is no longer a source of co-movement. In a second experiment (column six), we set the number of banks to $m = n = 10$ so that lending relationships between banks and sectors are one-to-one. In environments with idiosyncratic risk, an increase in the number of entities subject to such shocks is normally associated with a decay in aggregate volatility (cf. Gabaix, 2011). The reduction in the number of banks considered here substantially limits this diversification mechanism, resulting in an increase in aggregate volatility.

Finally, comparison across the various configurations of borrowing concentration and lending specialisation (columns two and three versus columns five and six) shows similar bank Herfindahl indices and levels of aggregate volatility. Importantly, however, and contrary to our previous findings from Table 5, the relative ranking of the Herfindahl indices levels is not aligned with that of the volatility levels. Although the numerical differences are moderate, this illustrates that in the distorted economy at hand the bank Herfindahl index is not necessarily an appropriate indicator for aggregate volatility: there is no proportionality between the bank Herfindahl index and the predicted level of aggregate volatility.[28]

5.4.4 Amplification?

The volatility expression in Proposition 3 makes clear that, whenever the the influence vector and the distortion influence vector diverge so that $\delta \neq 0$, aggregate volatility must be lower than predicted from the Herfindahl term alone. Consistent with that, Tables 5 and 6 indicate that, irrespective of the configuration of the intermediation and production networks, the bank Herfindahl index actually always exceeds the overall volatility factor.

It is thus useful to revisit the discussion following Proposition 3 from a quantitative perspective. There, we identified profit leakage as one key factor contributing to the dampening of aggregate volatility. Looking at our baseline parameterisation with decreasing returns to scale, but assuming financial frictions play no role, the expression for aggregate volatility is $var[\ln Y] = \sigma^2 \sum_{b=1}^{m} \left(\left(\frac{\eta\alpha}{1-\eta(1-\alpha)} \right)^2 s_b^2 \right)$. When $\eta = 0.85$, the cofactor in this expression

[28]Instead, the correct and economically relevant index for market concentration is given by the modified Herfindahl index computed based on the bank outdegrees weighted by the distortion influence vector, that is, the red line in panel (d) of Figure 3.

amounts to $\left(\frac{\eta\alpha}{1-\eta(1-\alpha)}\right)^2 = 0.64$. Relative to this technologically determined benchmark, the consideration of financial frictions with $\xi = 0.20$ changes this co-factor to $\left(\frac{\eta\alpha}{1-\zeta(1-\alpha)}\right)^2 = 1.44$. Accordingly, the direct effect of financial frictions is substantial amplification by a factor of $\frac{1.44}{0.64} = 2.25$.

The driving force behind this amplification is the factor substitution discussed in Lemma 1, which induces a rise in the intermediate input share from $\eta(1-\alpha) = 0.25$ to $\zeta(1-\alpha) = 0.50$, but also a fall in the total expenditure share from $\eta = 0.85$ to $\chi\alpha + \zeta(1-\alpha) = 0.70$. The amplification effect discussed above accounts only for the former effect via an increased network multiplier. The latter effect of financial frictions is accounted for via the additional outdegree correction term in Proposition 3. In line with (5.25), this term can be decomposed into an extra distortion term, $\left(\sum_{i=1}^n \delta_i\phi_{ib}\right)^2$, and another term, $2\frac{\alpha}{1-\zeta(1-\alpha)}s_b\sum_{i=1}^n \delta_i\phi_{ib}$, reflecting the interaction with the Herfindahl term. As seen in Tables 5 and 6, the extra distortion term is positive but only of moderate size; by contrast, the interaction term, which multiplies bank size with the relevant outdegree correction, is negative and sizeable. Taken together, these additional effects partially compensate the original amplification. For the baseline economy, dividing the 'overall' volatility factor by the technologically determined co-factor multiplied by the bank Herfindahl index results in an amplification factor of $\frac{0.0797}{0.64\times 0.0905} = 1.3754$. Hence, there is still substantial amplification relative to the benchmark without financial frictions. But the amplification is significantly smaller than the one predicted on the adjustment of intermediate input shares alone.

We conclude our discussion with an assessment of the empirical contribution of idiosyncratic credit supply shocks to the volatility of GDP in Uganda. Between January 2012 and June 2020, the quarterly volatility of log GDP was 1.72 per cent. Over the same time horizon, the volatility of the bank-level credit supply shocks identified in Section 5.4.1 was $\sigma^2 = 0.1098$ (cf. Appendix C.2.2). Relating these figures through our model (baseline calibration), we thus infer that the predicted level of aggregate volatility is 0.63 per cent ($0.1098 \times 0.0576 = 0.0063$).

That is, idiosyncratic credit supply shocks account for more than one third ($\frac{0.0063}{0.0172} = 0.3668$) of the empirically observed volatility. When the returns-to-scale parameter changes from its baseline value of $\eta = 0.85$ to $\eta = 0.7$ (low returns to scale) or $\eta = 0.99$ (CRS limit), the contribution changes to 9.2 per cent or 56.5 per cent, respectively. Hence, even though bank finance has a relatively small volume relative to GDP (low ξ), the financial sector can be an important source of aggregate volatility, particularly in environments with a limited extent of profit leakage. Notice also that similar calculations, which incorrectly rely on the Herfindahl term only, would significantly overstate this role.[29] Moreover, the experiments underlying Tables 5 and 6 demonstrate that the structure of financial intermediation summarised in the intermediation matrix $\mathbf{\Phi}$ has potentially significant implications on macroeconomic outcomes that are not necessarily captured via concentration measures alone.

5.5 Conclusion

The relationship between financial conditions and macroeconomic variables has been extensively studied in the developed economies. We present evidence from a different environment, namely a developing economy, where financial market are relatively less developed and subject to substantial financial frictions. In this paper we explore using network approach the transmission of idiosyncratic credit supply shocks to aggregate volatility in a developing economy. In demonstrating the implications of our theoretical results in an empirical application to Uganda, an economy defined by high bank dependence and concentration in the banking industry, the empirical results suggest that idiosyncratic shocks to credit supply have real consequences for bank-dependent sectors. Results from the counterfactual experiments show that configuration of the network plays a marginal part in determining aggregate volatility, whereas the architecture of financial intermediation has a bigger effect. In a banking system environ-

[29]For example, in the baseline economy the Herfindahl term would trace a share of 83.0 per cent of aggregate volatility ($\frac{0.1098 \times 0.85^2 \times 0.1804}{0.0172} = 0.8300$) back to credit supply shocks.

ment characterised by financial frictions, the Herfindahl index is no longer a sufficient statistic for explaining the banking sector's contribution to aggregate volatility. In addition, our theoretical model highlights an increased intermediate input share and increased profit leakage as the principal consequences of financial frictions. From a policy perspective this paper opens up a debate on how financial intermediation should be organised with respect to its implications for aggregate volatility. Results goes against the usual argument that we need to minimise bank size to reduce aggregate volatility.

Chapter 6

Conclusion and policy recommendations

The first two chapters speak to monetary policy efficacy, highlighting presence of balance sheet and sector borrowing transmission channels. In the first chapter, I document a balance sheet channel is operational and the real estate and agricultural sectors of the economy are disproportionately affected by tight monetary policy.

In the second chapter, I observed a sector borrowing channel is functional in Uganda, however, the role of the banks is important. I show regional and non-DSIB banks' borrowers can offset the impact of credit supply shocks from loans in all currencies. Local banks' borrowers are unable to offset shocks in both local and foreign currencies borrowing. Banks are more responsive to credit supply shocks, when loans are in foreign currencies this may affect monetary policy transmission.

In the third chapter, I investigate the impact of foreign exchange intervention on credit growth in Uganda. I find sterilised FX interventions dampen credit growth. The "crowding-out channel" is the main transmission mechanism at work, and the exchange rate transmission channel is insignificant. In the final chapter, we find the bank Herfindahl index is no longer a sufficient statistic to account for the banking system's contribution to aggregate volatility. The configuration of the production network plays a marginal part in determining aggregate volatility. However; financial intermediation has an important role in amplifying microeconomic shocks to the real economy. We finally find due to granularity and propagation mechanism via the intermediation and production network, bank-level supply shocks have sizeable real implications

Although, a number of monetary policy transmission mechanisms are at work in Uganda as observed, these mechanisms come at a price. The Ugandan economy is largely an agro-based economy, a reduction in credit to agriculture sector will affect the overall growth in the country. Also the real estate sector has the largest proportion of credit advanced to the private sector and a big reduction in credit will further dent growth in the country. This creates a policy dilemma for the Central Bank as growth enters into its objective function. When the banking system is subject to supply shocks local banks' borrowers are unable to adjust to these shocks. This suggests the banking system is not competitive and therefore calls for policies to enhance the competitiveness of the sector.

In terms of policy recommendations, when monetary, financial and foreign exchange intervention policies are implemented there is a need to coordinate policy across the various policy options. The Central Bank also needs to tighten policy gradually while allows for its impact to feed-through slowly. The Central Bank may need to adapt to a dual mandate of controlling inflation and economic growth as it is the case in the United States of America. As foreign currency lending increases, it is likely to reduce the effectiveness of monetary and financial stability policies. Therefore, foreign currency lending should be controlled. The banking sector needs increased competition and mobilisation of funding sources.

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Appendix A

Monetary Transmission Mechanism in Uganda, evidence from Banks' sectoral lending data

Information on economic sectors is Uganda, is compiled by Uganda Bureau of Statistics(UBOS).The Uganda Business inquiry(UBI)[1] [2] is a comprehensive economic survey conducted every 5-10 years with the latest data collected in fiscal year 2009/2010. Data collected is used to compile indicators such as value added, gross fixed capital, gross output and intermediate consumption. The economic sectors are classification according to the International Standard Industrial classification.

[1]Over 2 million businesses are covered of which 96 per cent are considered informal and contributing to 31 per cent of the total value added this includes all non-tax paying households

[2]Data on personal and household sector is considered as part of the informal sector.

A.1 Agriculture sector

The Agriculture sector contributed to 24 per cent of the gross domestic product (GDP) and 4 per cent of value added(VA) in the fiscal year 2009/2010 as shown in table 10[3]. The highest component of the sector's value added was profit that contributed to 37 per cent of the total value added, while the lowest component was bad debt at 0.1 per cent of the total value added. Labour productivity per worker of the agriculture sector was 800 thousand shillings, which was well below the 12 million shillings total productivity per person for all sectors. The agriculture sector reported a liquidity ratio of 0.5 which is less than the 1.2 bench mark used in the survey. This implies that the sector struggles to meet its short-term obligations. The sector's ability to meet its long-term debts was reported at 0.7 per cent meaning that the sector could cover at least 70 per cent of its debts. The agricultural sector reported a profitability of 16 percentage which was above the 9 per cent target observed in the survey. At 30 per cent, the sector employs the highest share of people working in the formal sector. These observations suggest that the sector has low productivity, low output and sector is not so depended on credit facilitates.

A.2 Manufacturing

The manufacturing sector contributed a share of 8 per cent of total GDP in 2009/10 as reported in the UBOS statistical Abstract 2011. The sector's value-added ratio was estimated at 0.9, implying value addition contributed to 90 per cent of its total output. The manufacturing sector reported a liquidity ratio of 2.2 which is above the benchmark and therefore this suggests that the sector could meet its short-term obligations. The debt ratio as defined as the ratio of total debt to total assets stood at 0.4 which is low implying the corporate capital structures of this sector was geared towards to more equity financing as opposed to debt. The sector's

[3] VA:GO is the ratio of value added to gross output and IC:GO is the ratio of intermediate consumption to gross output

profitability was 8.7 per cent just below the overall total profitability of 9 per cent reported in the survey. Labour productivity was 19.1 million per employed worker over the 12 million total productivity per worker reported by all businesses. The sector also employs about 22 per cent of people employed in the formal sector.

A.3 Mining and quarrying

The mining and quarrying sector contributed 0.3 per cent to GDP in the fiscal year 2009/2010. The sector registered a ratio of value added to output ratio of 0.51, with net profit as the main driver of value added. The sector commands the largest share of total non-current assets.It also employs less than 1 percent of people employed in the formal sector.Information of performance indicators for this sector were not available however, we can deduce that output from the sector is low and less capital intensive.

A.4 Building, mortgage, construction and real estate

Construction sub-sector reported a current ratio of 1.6 which is broadly in between the acceptable rage of 1.5 and 3 for a business to be considered healthy. Overall profitability was reported at 11 per cent for the sub sector. The sub-sector is dependent on debt as the debt ratio was recorded at 63 per cent. Labour productivity was recorded at 12.8 million per employed per son which was slightly above the total productivity 12-million-shilling per worker for all sectors. The real estate sub-sector also reported value added to gross output ratio of 56.0 per cent and the highest component of value added was the cost of staff. Although, it employs less than 1 per cent of people in the formal sector,it contributes to about 9.3 of the gross output. The sector has also enjoyed high growth rates in recent past, however, of late growth has slowed down and this has been attributed to the tight monetary policy stance adopted by the central bank.

A.5 Utilities

The production, generation of electricity contributed to 1.2 per cent of GDP in current prices [4] while purification and distribution of water was estimated at 3.3 per cent of GDP at current prices in the fiscal year 2009/2010. The ratio of value added to gross output declined from 77 recorded in 2000/2001 to 66 per cent suggesting that the cost of production increased. The labour productivity ratio of the sector was 17.7 million as compared to 12 million for all sectors. Financing of the utilities sector by debt was recorded at 37 per cent as defined by the debt ratio.

A.6 Trade

The trade sector contributed to about 12 per cent of the total GDP in the fiscal year 2009/2010 [5] according UBOS Statistical Abstract 2011. It also reported the highest value added, with net profit as the highest contributor to value added figure. The ratio of value added to gross output approximated at 68 per cent in 2009/10 compared to 63 per cent reported in 2000/2001. Labour productivity for the sector was 10 million per person employed compared to the total productivity of all sectors of 12 million per employed person. The ability of the trade sector to cover its short-term obligation was recorded at 1.9 as measured by the liquidity ratio implying the sector was in position to meet its short-term liabilities. In terms of long-term debt obligations, the debt ratio for the sector was recorded at 0.3, this low figure suggests that the sector is not largely financed by debt. The trade sector registered a 10 per cent profitability,

[4] Gross domestic product at prices of the current reporting period

[5] Recent GDP data is split into three broad categories Agriculture, Industry and services and therefore not applicable

with vehicle sales and retail trade sub-sectors reporting the highest profitability of about 15 per cent each as noted by the UBI survey. The sector employs 21 per cent of people in the formal sector.

A.7 Community, social and other services

This sector includes several sub-sectors namely: accommodation and food services, arts, entertainments and recreation, education, human health and social work and finally other services. Accommodation and food services recorded a value added to gross output ratio of 0.7 in 2009/2010 implying the sector had a high efficiency levels in input utilisation, also net profit was the biggest contributor to value added measure. We note that this sub-sector is dependent on equity and reserves for its funding, with loans contributing about 17 per cent of its funding. The education subsector, had a liquidity ratio of 6.5 per cent, a profitability of 16 per cent and with a debt ratio of 0.1, implying the sub-sector could meet its long-term obligations with ease. As a sub-component of this sector the health sector reported a value added to gross output ratio of 64 per cent in fiscal year 2009/2010. The sub-sector had a liquidity ratio of 2.4 implying the sub-sector could meet its short-term obligations. The sector recorded a debt ratio of 0.2 and labour productivity of 13 million compare to the total productivity of 12 million per person employed across all sectors. The community,social and other services sector also employs 18 per cent of people working in the formal sector.

A.8 Transport and communication

The transport and communication sector contributed to 6.4 per cent to GDP in the fiscal year 2009/2010. The ratio of value added to gross output was recorded at 18 per cent, with the cost of staff contributing 39 per cent of the value added as the highest component. The information and communication sub-sector's value to gross output ratio was 48 per cent and the its profitability was minus 9 percent. The sub-sector had a liquidity ratio of 0.6 that meant the sub-sector was failing to meet its short-term obligations. The sub-sector had a debt-ratio of 0.6 implying 60 percent of the its total assets was debt and labour productivity of 41 million per person.

A.9 Business services

The finance and insurance sub-sector contributed to about 3 per cent of GDP in fiscal year 2009/2011 according to UBOS Statistical Abstract 2011. The sub-sector had a value added to gross output ratio of 37 per cent in 2009/2010 compared to 77 per cent in 2000/2001.It employs about 6 per cent of people working in the formal sector. With the ratio of value added to gross output estimated at about 48 per cent.

In terms of sectors of the economy, it is argued that the big borrowers will continue borrowing while the small firms face credit rationing when monetary policy is tightened. In a developing country like Uganda, contractionary monetary policy may significantly affect some important sectors of the economy, a case may be the agricultural sector that is characterised by lower collateralised net value, low survival rates, low and volatility output as noted earlier, and yet the sector also employs the largest proportion of the population. A Bank of Uganda financial stability report (June 2016) reports that non-performing loans (NPL) of the building, construction and real estate sector increased by 11.6 per cent in June 2016 from 6.7 per cent in December 2015 as measured in the local currency.The agriculture sector's NPL increased by 11.8 per cent in June 2016 from 6.7 per cent observed in December 2015. Trade and commerce sector's NPL increased by UGX 10.8 per cent from 7.1 per cent in December 2015, this can be seen in Table A.2 [6]. As the asset quality of the banking sector deteriorates it is expected for

[6] UGX represents the Ugandan shilling and FX represents foreign currencies

banks to reduce lending to these sectors as they are perceived to be less credit worthy hence the balance sheet transmission channel. It may also restrict investment so much so that it may induce a recession as the cost of capital increases disadvantaging some sectors of the economy. This paper will investigate for evidence of whether some sectors in the Ugandan economy are disproportionately affected by monetary policy.

	Employment share	Gross Output	Value Added	VA:GO	IC:GO
Agriculture, Forestry and Fishing	30.4	1721485	1131430	65.7	34.3
Mining and Quarrying	0.4	280209	140572	50.2	49.8
Manufacturing	21.8	7094311	5206243	73.4	26.6
Utilities	0.0	572931	379395	66.2	33.8
Construction and real estate	0.6	3978372	3333689	83.8	16.2
Trade	20.8	9529806	6444548	67.6	32.4
Transport and communication	2.5	6869878	2365491	34.4	65.6
Community and other services	17.9	5451659	3609379	66.2	33.8
Business services	5.7	7497916	3579753	47.7	52.3
Total	100	42996566	26190498	60.9	39.1

Source: Uganda Bureau of Statistics, UBI-2009/2010.

Table A.1: Industry sector showing employment shares, gross output and value added

		Jun-15	Dec-15	Jun-16
Agriculture	UGX	4.6	6.7	11.8
	FX	7.5	23.7	21.9
Manufacturing	UGX	7.8	0.8	6.0
	FX	2.7	0.2	0.6
Trade and commerce	UGX	2.6	7.1	10.8
	FX	5.2	1.4	7.0
Building, construction and real estate	UGX	2.6	6.7	11.6
	FX	5.2	5.6	10.7
Personal and household loans	UGX	4.0	4.5	3.8
	FX	5.7	4.8	1.9
Industry ratio	UGX	3.8	5.0	8.3
	FX	4.2	5.6	8.3

Source: Bank of Uganda.

Table A.2: Sectoral Non-performing loans ratios by currency(percentage)

	Levels(Constant,trend)	Constant only	First diff (Constant, trend)	Constant	Conclusion
GDP	-3.35[0.07](7)	-2.04[0.27](4)	-4.93[0.00](1)	-4.95[0.00](1)	Non-stationary
Policy rate	-3.96 [0.01] (10)	-4.15 [0.00] (10)	-3.71[0.03] (1)	-3.58[0.01] (1)	Stationary
Liquidity	-4.27 [0.00] (4)	-2.82[0.06] (0)	-11.54[0.00] (0)	-11.22[0.00] (0)	Stationary
Capital	-2.56[0.30] (0)	-1.89[0.34] (0)	-9.87[0.00] (0)	-9.86[0.00] (0)	Non-stationary
Asset	-3.40[0.06](0)	-1.85[0.36] (2)	-9.30[0.00] (1)	-9.10[0.00] (0)	Stationary
Agriculture	-3.40[0.06](0)	-1.17[0.94](0)	-7.17[0.00](0)	-7.12[0.00](0)	Stationary
Trade	-2.86[0.56](0)	-3.50[0.05](0)	-8.88[0.00](0)	-8.86[0.00](0)	Stationary
Household	-2.74[0.22](0)	-2.07[0.26](0)	-9.45[0.00](0)	-9.43[0.00](0)	Non-stationary
Transport	-1.94[0.62](0)	-1.93[0.32](0)	-10.19[0.00](0)	-10.19[0.00](0)	Non-stationary
Manfacturing	-2.74[0.22](0)	-2.38[0.15](0)	-8.70[0.00](0)	-8.52[0.00](0)	Non-stationary
Real Estate	-2.94[0.16](0)	-1.16[0.69](1)	-5.95[0.00](0)	-10.64[0.00](0)	Non-stationary
Community	-4.72[0.00](0)	-4.52[0.00](0)	-12.36[0.00](0)	-12.45[0.00](0)	Stationary
Business	-4.12[0.00](0)	-3.67[0.01](0)	-9.84[0.00](0)	-9.91[0.00](0)	Stationary
Electricity	-3.73[0.03](0)	-2.80[0.06](0)	-10.15[0.00](0)	-10.15[0.00](0)	Stationary
Mining	-3.07[0.12](0)	-2.27[0.19](0)	-10.42[0.00](0)	-10.50[0.00](0)	Non-stationary

Source: Author's computation.

Table A.3: ADF unit-roots test for the aggregated data

	Levels(Trend)	Drift only	Conclusion
Capital	213.78[0.00] (8)	126.70[0.00](5)	stationary
Liquidity	80.09[0.00] (2)	190.69[0.00](1)	stationary
Return on Asset	139.19[0.00] (3)	140.99[0.00](1)	stationary
Asset	291.95[0.00](8)	121.57[0.00](3)	stationary
GDP	167.01 [0.00] (0)	146.66 [0.00](5)	stationary
Policy rate	256.63 [0.00](3)	113.45[0.00] (3)	stationary
Agriculture	100.58[0.00](1)	171.57[0.00] (1)	stationary
Manufacturing	158.10[0.00](1)	145.78[0.00] (3)	stationary
Trade	69.78[0.00](1)	160.85[0.00] (1)	stationary
Transport	124.47[0.00](2)	110.26[0.00] (5)	stationary
Real Estate	103.63[0.00] (4)	166.60[0.00] (1)	stationary
Community	148.36[0.00] (1)	72.50[0.02] (1)	stationary
Household	121.67[0.00] (3)	116.05[0.00](1)	stationary
Business	127.75[0.00](3)	134.97[0.00](2)	stationary

Source: Author's computation.

Table A.4: Fisher test for the panel data

Table A.5: VECM results of the aggregated data.

Variables	Coefficients
D_Policy rate	
L._longrun	-0.101***
	(-3.97)
L._longrun	-1.917***
	(-4.02)
Lag1.Policy rate	-0.267
	(-1.92)
Lag2.Policy rate	0.159
	(1.23)
Lag3.Policy rate	-0.174
	(-1.19)
Lag1.Agriculture	0.612
	(1.12)
Lag2.Agriculture	1.849***
	(3.42)
Lag3.Agriculture	0.326
	(0.65)
Lag1.Mining	8.853***
	(3.56)
Lag2.Mining	5.267*
	(2.26)
Lag3.Mining	4.563*
	(2.40)
Lag1.Manufacturing	0.849*

Continued on next page

Variables	Coefficients
	(2.03)
Lag2.Manufacturing	0.774*
	(2.13)
Lag3.Manufacturing	1.025***
	(3.42)
Lag1.Transport	0.554
	(1.20)
Lag2.Transport	0.492
	(0.96)
Lag3.Transport	1.026**
	(2.66)
Lag1.Trade	0.910*
	(2.38)
Lag2.Trade	1.161**
	(3.19)
Lag3.Trade	0.322
	(1.10)
Lag1.Electricity	1.691*
	(2.00)
Lag2.Electricity	1.949*
	(2.52)
Lag3.Electricity	1.274
	(1.70)
Lag1.Business	2.159 ***
	(3.37)
Lag2.Business	1.610**
	(2.70)

Continued on next page

Variables	Coefficients
Lag3.Business	0.364
	(0.91)
Lag1.Community	1.181
	(1.34)
Lag2.Community	0.306
	(0.39)
Lag3.Community	0.222
	(0.35)
Lag1.RealEstate	1.308**
	(3.25)
Lag2.RealEstate	0.937**
	(2.93)
Lag3.Real Estate	0.559*
	(2.16)
Lag1.Household	0.968**
	(3.02)
Lag2.Household	0.622*
	(2.25)
Lag3.Household	0.414
	(1.88)
_Constant	-0.0265
	(-0.28)
N	65

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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Variables	**Coefficients**
Source: Bank of Uganda and author's computations	

Variable	chi2	df	Prob > chi2
Policy rate	0.9	2	0.63775
Agriculture	5.458	2	0.06529
Mining	4.563	2	0.10214
Manufacturing	1.305	2	0.52077
Transport	0.619	2	0.73373
Trade	0.156	2	0.92493
Electricity	1.445	2	0.4856
Business	2.405	2	0.30045
Community	2.557	2	0.27839
Real Estate	0.199	2	0.90547
Household	1.126	2	0.56955
All	20.732	22	0.53734

Table A.6: Tarque Bera test for Normality

lag	chi2	df	Prob > chi2
1	115.8358	121	0.61554
2	132.9505	121	0.2157
3	122.165	121	0.45324
4	123.619	121	0.41685

Table A.7: Test for auto-correlation

	Trade	Manuf	Pers	Trans	Agric	Estate	Elect	Comm	Mining
L.Trade	0.728***								
	(10.96)								
L2.Trade	-0.331***								
	(-3.83)								
L3.Trade	0.165*								
	(2.25)								
policy	0.00571	0.000176	-0.00297	-0.00429	0.0223	-0.0646**	-0.00412	0.00650	0.0428*
	(1.10)	(0.06)	(-1.46)	(-0.30)	(1.49)	(-2.81)	(-1.61)	(1.78)	(2.06)
L.policy	-0.0104*	0.00152	-0.00273	-0.00482	0.0211	-0.0224	0.00350*	-0.00689	-0.0239
	(-2.14)	(0.30)	(-1.05)	(-0.43)	(1.53)	(-0.96)	(2.08)	(-1.70)	(-1.55)
L2.policy	0.00277	-0.00334	-0.00564	-0.0272*	-0.0452***	0.0254	-0.00291	0.00564**	0.0132
	(0.68)	(-1.10)	(-1.41)	(-2.33)	(-3.83)	(1.06)	(-1.42)	(2.67)	(1.24)
L3.policy	-0.00205	0.000771	0.00499*		0.0389*				
	(-0.44)	(0.42)	(2.14)		(2.48)				
liquid	-0.000522				0.000113	-0.00263*	-0.00127*	0.00202	0.0000552
	(-1.19)				(0.78)	(-2.03)	(-2.03)	(1.90)	(0.10)
L.liquid	0.000627				0.0000973	0.00171	0.000958*	-0.00224	0.000310
	(1.24)				(0.39)	(1.03)	(2.00)	(-1.68)	(0.67)
L2.liquid	0.000125				0.0000167	0.000998	-0.00106	0.00155*	0.000544
	(0.29)				(0.09)	(0.67)	(-1.56)	(2.15)	(1.89)
L3.liquid	0.000700				0.000365*				
	(1.30)				(2.22)				
profit	-0.0178		-0.00234*	0.000829			0.000802	-0.000347	
	(-1.72)		(-2.00)	(1.70)			(1.61)	(-0.47)	

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	Trade	Manuf	Pers	Trans	Agric	Estate	Elect	Comm	Mining
L.profit	0.00764		-0.000900	0.00172			-0.00163	-0.00166	
	(0.78)		(-0.39)	(1.47)			(-1.32)	(-0.87)	
L2.profit	0.0197		-0.00156	-0.00124			-0.000955	0.00135*	
	(1.84)		(-1.15)	(-1.22)			(-1.50)	(2.07)	
L3.profit	-0.0175*		0.00733*						
	(-2.04)		(2.18)						
L2.gdp_grow	-0.000609					-0.00389**			
	(-0.55)					(-3.10)			
L3.gdp_grow	0.00115								
	(0.68)								
capital	0.00445**	0.000381							0.00121*
	(2.65)	(0.26)							(1.99)
L.capital	-0.00497*	0.00192							-0.000120
	(-2.24)	(0.81)							(-0.19)
L2.capital	-0.00222	-0.00332**							0.000327
	(-1.25)	(-2.95)							(0.86)
L3.capital	0.00102	0.00235***							
	(0.49)	(4.06)							
Demand	-0.00971**	0.0000186	0.00755*	0.000328	0.00335	-0.00120	-0.000226	0.00391**	0.000542
	(-3.11)	(0.01)	(2.11)	(0.27)	(1.26)	(-0.31)	(-0.19)	(3.21)	(0.96)
L.Demand	0.00217	0.00392*	-0.000603	0.000413	-0.00274	-0.00785*	-0.00000606	-0.00312*	0.000555
	(0.51)	(1.99)	(-0.38)	(0.45)	(-1.29)	(-2.02)	(-0.01)	(-2.46)	(0.72)
L2.Demand	-	-0.00507	-0.00206***	0.00221	0.000555*				

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	Trade	Manuf	Pers	Trans	Agric	Estate	Elect	Comm	Mining
	(-0.52)	(0.09)	(-0.30)	0.000170	-	-	0.000646	(-0.98)	(0.42)
			0.00262		0.000446	0.00211			
(-1.56)	(-3.85)	(0.89)	(2.35)						
Trans*cap	-								
	0.000365								
	(-1.87)								
L.Trans*cap	0.000494*								
	(2.02)								
L.Manuf		0.642***							
		(6.69)							
L2.Manuf		-0.0926							
		(-1.66)							
L3.Manuf		-							
		0.0821**							
		(-2.66)							
ln_asset		0.0311*		-	0.0359*		0.0195		0.0382
				0.00865					
		(2.16)		(-0.45)	(2.40)		(0.65)		(1.79)
L.ln_asset		0.00192		-0.0178	0.0389		-0.0256		-0.0369
		(0.16)		(-1.02)	(1.50)		(-1.09)		(-1.08)
L2.ln_asset		0.0346*		-0.0273	-		0.0250		0.00736
					0.0642*				
		(2.13)		(-1.57)	(-2.02)		(1.03)		(0.44)
L3.ln_asset		-			0.0721*				
		0.00865							
		(-0.49)			(2.46)				
L2.Manuf*cap		0.000271*							
		(2.04)							
L3.Manuf*cap		-							
		0.000117							
		(-1.55)							
L.Pers			0.732***						

Continues on the next page

	Trade	Manuf	Pers	Trans	Agric	Estate	Elect	Comm	Mining
			(12.84)						
L3.Pers*cap			-0.000164*						
			(-2.00)						
L.Trans				0.881***					
				(7.66)					
L2.Trans				-0.256*					
				(-2.23)					
L2.Trans*asset				0.00323*					
				(2.29)					
L.Agric					0.786***				
					(11.68)				
L2.Agric					-0.231***				
					(-3.98)				
L2.Agric*asset					0.00528***				
					(3.76)				
L3.Agric*asset					-0.00465**				
					(-2.58)				
L.Estate						0.680***			
						(4.85)			
L2.Estate*ROA						-0.000328*			
						(-2.29)			
Estate*Asset						0.00620**			
						(2.68)			
L.Elect							0.749**		
							(3.10)		
L.Comm								0.816***	
								(12.29)	

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	Trade	**Manuf**	**Pers**	**Trans**	**Agric**	**Estate**	**Elect**	**Comm**	**Mining**
L2.Comm								-0.233***	
								(-3.67)	
L3.Comm								0.179***	
								(5.79)	
L2.Comm*liquid								-0.000255***	
								(-4.19)	
L.Mining									1.003***
									(7.48)
L2.Mining									-0.271**
									(-2.60)
Mining*asset									-0.00427*
									(-2.06)
L2.Mining*Liquid									-0.0000724*
									(-2.24)
N	331	324	297	351	331	358	322	351	341

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix B

Does a sector borrowing channel exist in Uganda?

Regional banks	Domestic banks(Local)	International banks
Ecobank	DFCU	Bank of Baroda
Bank of Africa	Centenary bank	Standard Chartered
KCB	Housing Finance	ABSA (formerly Barclays)
DTB	Orient bank	
Equity Bank		
Cairo Bank		
Stanbic Bank		
Tropical Bank		
United Bank for Africa		

Source: Bank of Uganda.

[a] Excludes new banks licensed after 2018;Opportunity Bank, Finance Trust, NCBA(following merger of NC Bank and CBA in 2020).
[b] Domestic(local) banks are banks with headquarters and majority shareholding, Ugandan resident.
[c] Regional banks are institutions controlled and owned from other regional countries on the African continent.
[c] International banks, these are multinational banks that have headquarters and majority share holding based overseas.
[d] Crane Bank limited excluded from the analysis.

Table B.1: Bank classification by the origin of bank.

Appendix C

Credit supply shocks and aggregate volatility: A network approach

C.1 Theoretical results

C.1.1 Proof of Lemma 1

Using (5.1), (5.2) and (5.9), sectoral output can be written as $q_i = q_i(x_i, q_{ij})$. The problem faced by intermediate good firms thus becomes

$$\max_{x_i, q_{ij}} \pi_i = p_i q_i(x_i, q_{ij}) - r_i x_i - \sum_{j=1}^{n} p_j q_{ij} + \lambda \left[\xi p_i q_i(x_i, q_{ij}) - r_i x_i \right],$$

where $\lambda \geq 0$ is the Lagrange multiplier on financial constraint (5.10). The optimality conditions for x_i and q_{ij} are

$$(1+\lambda\xi)\frac{\eta\alpha p_i q_i}{x_i} = (1+\lambda)r_i,$$
$$(1+\lambda\xi)\frac{\eta(1-\alpha)\omega_{ij} p_i q_i}{q_{ij}} = p_j.$$

Hence,

$$x_i = \frac{(1+\lambda\xi)}{(1+\lambda)}\frac{\eta\alpha p_i q_i}{r_i} \leq \frac{\eta\alpha p_i q_i}{r_i},$$
$$q_{ij} = (1+\lambda\xi)\frac{\eta(1-\alpha)\omega_{ij} p_i q_i}{p_j} \geq \frac{\eta(1-\alpha)\omega_{ij} p_i q_i}{p_j},$$

where the inequalities follow because $\xi \in (0,1)$. Let $\chi \equiv \frac{(1+\lambda\xi)}{(1+\lambda)}\eta$ and $\zeta \equiv (1+\lambda\xi)\eta$. As $\xi \in (0,1)$, we have $\xi\eta < \chi \leq \eta$. Moreover, $(1+\lambda\xi)\eta = (1+\lambda)\chi$ and hence $\lambda = \frac{\eta-\chi}{\chi-\xi\eta} \geq 0$ and $\zeta = (1+\lambda)\chi \geq \eta$. The demand for the loan aggregate, labor and intermediate inputs can thus be written as

$$x_i = \frac{\chi\alpha p_i q_i}{r_i},$$
$$\ell_i = \frac{x_i}{w} = \frac{\chi\alpha p_i q_i}{r_i w},$$
$$q_{ij} = \frac{\zeta(1-\alpha)\omega_{ij} p_i q_i}{p_j}.$$

Finally, when $\xi < \eta\alpha$, the financial constraint (5.10) is strictly binding and $\chi = \frac{\xi}{\alpha} < \eta$. This implies $\lambda = \frac{\eta-\chi}{\chi-\xi\eta} = \frac{\eta\alpha-\xi}{\xi(1-\eta\alpha)} > 0$, and $\zeta = (1+\lambda\xi)\eta = \frac{1-\xi}{1-\eta\alpha}\eta > \eta$. The demand for bank loans x_{ib} is obtained from the loan expenditure minimization problem

$$\min_{x_{ib}} \sum_{b=1}^{m} r_b x_{ib}$$

subject to $\prod_{b=1}^{m} x_{ib}^{\phi_{ib}} = x_i$. The associated optimality condition is

$$r_b = \mu \frac{\phi_{ib} x_i}{x_{ib}},$$

where $\mu > 0$ is a Lagrange multiplier. Hence,

$$\sum_{b=1}^{m} r_b x_{ib} = \sum_{b=1}^{m} \mu \phi_{ib} x_i = \mu x_i = \mu \prod_{b=1}^{m} x_{ib}^{\phi_{ib}},$$

and

$$x_i = \prod_{b=1}^{m} x_{ib}^{\phi_{ib}} = \prod_{b=1}^{m} \left(\mu \frac{\phi_{ib} x_i}{r_b} \right)^{\phi_{ib}} = \mu x_i \prod_{b=1}^{m} \left(\frac{\phi_{ib}}{r_b} \right)^{\phi_{ib}}.$$

Solving for μ, we obtain the loan price index,

$$\mu = \prod_{b=1}^{m} \left(\frac{r_b}{\phi_{ib}} \right)^{\phi_{ib}} = r_i.$$

Substituting into the loan optimality condition, we obtain

$$x_{ib} = \mu \frac{\phi_{ib} x_i}{r_b} = \frac{\phi_{ib} r_i x_i}{r_b} = \frac{\chi \alpha \phi_{ib} p_i q_i}{r_b},$$

where the last equality makes use of the demand condition for the loan aggregate. Total expenditures are given by

$$r_i x_i + \sum_{j=1}^{m} p_j q_{ij} = \left[\alpha \chi + (1 - \alpha) \zeta \right] p_i q_i.$$

When the financial constraint (5.10) is strictly binding, $\chi = \frac{\xi}{\alpha}$ and total expenditures are

$$\left[\alpha \chi + (1 - \alpha) \zeta \right] p_i q_i = \left[\alpha \frac{\xi}{\eta \alpha} + (1 - \alpha) \frac{1 - \xi}{1 - \eta \alpha} \right] \eta p_i q_i.$$

The expression in brackets is continuous in ξ and converges to one as $\xi \to \eta\alpha$. Its derivative with respect to ξ is given by

$$\frac{d}{d\xi}\left[\alpha\frac{\xi}{\eta\alpha} + (1-\alpha)\frac{1-\xi}{1-\eta\alpha}\right] = \frac{1}{\eta} - \frac{1-\alpha}{1-\eta\alpha} > 0.$$

Hence, $\left[\alpha\frac{\xi}{\eta\alpha} + (1-\alpha)\frac{1-\xi}{1-\eta\alpha}\right] < 1$ when $\xi < \eta\alpha$. It follows that, under a binding financial constraint, total expenditures are strictly smaller than their level in the absence of the constraint,

$$r_i x_i + \sum_{j=1}^{m} p_j q_{ij} < \eta p_i q_i.$$

C.1.2 Proof of Lemma 2

As seen in the proof of Lemma 1, total expenditures under a binding financial constraint (5.10) are given by

$$[\alpha\chi + (1-\alpha)\zeta]\, p_i q_i = \left[\alpha\frac{\xi}{\eta\alpha} + (1-\alpha)\frac{1-\xi}{1-\eta\alpha}\right]\eta p_i q_i.$$

The derivative of the expression in brackets with respect to α is given by

$$\frac{d}{d\alpha}\left[\alpha\frac{\xi}{\eta\alpha} + (1-\alpha)\frac{1-\xi}{1-\eta\alpha}\right] = -\frac{(1-\xi)(1-\eta)}{(1-\eta\alpha)^2} < 0.$$

C.1.3 Proof of Proposition 1

Derivation of the influence vector. From (5.3), market clearing for output goods implies

$$c_j + \sum_{i=1}^{n} q_{ij} = q_j.$$

Using (1) to substitute for q_{ij} and multiplying by p_j,

$$p_j c_j + \sum_{i=1}^{n} \zeta(1-\alpha)\omega_{ij} p_i q_i = p_j q_j.$$

Using (5.14) to substitute for prices and simplifying,

$$\beta_j + \sum_{i=1}^{n} \zeta(1-\alpha)\omega_{ij} \beta_i \frac{q_i}{c_i} = \beta_j \frac{q_j}{c_j}.$$

Defining $\gamma_i \equiv \beta_i \frac{q_i}{c_i}$,

$$\beta_j + \sum_{i=1}^{n} \zeta(1-\alpha)\omega_{ij} \gamma_i = \gamma_j. \tag{C.1.1}$$

In vector notation, stacked over sectors, this becomes

$$\beta + \zeta(1-\alpha)\mathbf{W}'\gamma = \gamma.$$

Solving for γ,

$$\gamma = \left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}'\right]^{-1} \beta. \tag{C.1.2}$$

Notice that the elements of γ can be written as

$$\gamma_i = \beta_i \frac{q_i}{c_i} = \frac{p_i c_i}{PC} \frac{q_i}{c_i} = \frac{p_i q_i}{Y},$$

where we used (5.14), the normalization for the aggregate price level, $P = 1$, and the fact that final output coincides with aggregate consumption, $Y = C$. That is, the elements of γ are given by the sectoral ratio of total intermediate good sales relative to final output. Notice from (C.1.1) that

$$\sum_{i=1}^{n} \gamma_i = \frac{1}{1-\zeta(1-\alpha)},$$

which converges to $\frac{1}{\alpha}$ as the expenditure coefficient for intermediate inputs approaches its value under constant returns to scale ($\eta = 1$) and no financial frictions ($\xi > \eta\alpha$), $\zeta \to 1$.[1] Multiplication of the sales vector in (C.1.2) with α yields the influence vector,

$$\mathbf{v} = \alpha\gamma = \alpha \left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}'\right]^{-1} \beta, \tag{C.1.3}$$

with transpose

$$\mathbf{v}' = \alpha\beta' \left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}\right]^{-1}. \tag{C.1.4}$$

Notice that the multiplication with α implies

$$\sum_{i=1}^{n} v_i = \sum_{i=1}^{n} \alpha\gamma_i = \frac{\alpha}{1-\zeta(1-\alpha)},$$

indicating that, when $\zeta = 1$, the elements of the influence vector sum to one and correspond to the sectoral shares of total intermediate good sales – the Domar weights. However, when $\zeta \neq 1$, this equivalence is lost.**Financial frictions and the influence vector.** Notice that the input-output matrix $\mathbf{W}$ is positive and that all the eigenvalues of $\mathbf{W}$ are inside the unit circle. Applying the Perron-Frobenius Theorem, we can then express the influence vector as a Neumann series,

$$\mathbf{v}' = \alpha\beta' \sum_{k=0}^{\infty} \left[\zeta(1-\alpha)\right]^k \mathbf{W}^k.$$

[1]Given the technology in (5.2), when $\eta = 1$ and $\xi > \eta\alpha$, final output amounts to a share α (the labor share, corresponding to the remuneration of the only primary input) of total intermediate good sales; the remaining share $(1-\alpha)$ is netted out for expenditure on intermediate inputs.

Post-multiplying by a vector of ones,

$$\mathbf{v}'\mathbf{1} = \alpha\beta' \sum_{k=0}^{\infty} \left[\zeta(1-\alpha)\right]^k \mathbf{W}^k \mathbf{1}.$$

The geometric series converges as $|\zeta(1-\alpha)| < 1$. Hence,

$$\mathbf{v}'\mathbf{1} = \alpha\beta' \sum_{k=0}^{\infty} \left[\zeta(1-\alpha)\right]^k \mathbf{1} = \frac{\alpha \sum_{i=1}^{n} \beta_i}{1-\zeta(1-\alpha)} = \frac{\alpha}{1-\zeta(1-\alpha)}, \tag{C.1.5}$$

which is different from one, unless $\zeta = 1$. Notice that $\frac{\alpha}{1-\zeta(1-\alpha)} > 1$ holds if $\zeta > 1$, which is true provided the extent of financial frictions as captured by the shortfall of ξ below $\eta\alpha$ is sufficiently strong relative to the extent of decreasing returns to scale $\eta < 1$. Formally, $\zeta = \frac{1-\xi}{1-\eta\alpha}\eta > 1$ if $\frac{1-\xi}{1-\eta\alpha} > \frac{1}{\eta}$. By contrast, under moderate financial frictions, we have $\zeta < 1$ and hence $\frac{\alpha}{1-\zeta(1-\alpha)} < 1$. Recall from the proof of Lemma 1 that, under a binding financial constraint, we have $\zeta = \frac{1-\xi}{1-\eta\alpha}\eta$ with $\frac{d\zeta}{d\xi} = -\frac{\eta}{1-\eta\alpha} < 0$. Since the ratio in (C.1.5) is increasing in ζ, it follows that tighter financial frictions (that is, a reduction in ξ in the range where constraint (5.10) is binding) lead to an increase in $\mathbf{v}'\mathbf{1} = \sum_{i=1}^{n} v_i$.

C.1.4 Equilibrium

Derivation of intermediate input demand. From (5.14) and the definition of γ_i, we have

$$\frac{p_i}{p_j} = \frac{c_j}{c_i}\frac{\beta_i}{\beta_j} = \frac{q_j}{q_i}\frac{\gamma_i}{\gamma_j}.$$

From (1), we have

$$q_{ij} = \zeta(1-\alpha)\omega_{ij} q_i \frac{p_i}{p_j}.$$

Substituting for $\frac{p_i}{p_j}$ from the previous equation, and using the relationship $v_i = \alpha\gamma_i$, we get

$$q_{ij} = \zeta(1-\alpha)\omega_{ij} q_j \frac{\gamma_i}{\gamma_j} = \zeta(1-\alpha)\omega_{ij} q_j \frac{v_i}{v_j}. \tag{C.1.6}$$

Derivation of loan demand and bank market shares. From (**??**) and the definition of γ_i, we have

$$x_{ib} = \frac{\chi\alpha\phi_{ib}p_i q_i}{r_b} = \frac{\chi\alpha\phi_{ib}\frac{p_i c_i}{\beta_i}\gamma_i}{r_b}.$$

From (5.14), $\frac{p_i c_i}{\beta_i} = \frac{p_j c_j}{\beta_j}$ so that

$$x_{ib} = \frac{\chi\alpha\frac{p_j c_j}{\beta_j}}{r_b}\phi_{ib}\gamma_i. \tag{C.1.7}$$

Summing (C.1.7) across sectors,

$$\sum_{i=1}^{n} x_{ib} = \frac{\chi\alpha\frac{p_j c_j}{\beta_j}}{r_b}\sum_{i=1}^{n}\phi_{ib}\gamma_i.$$

The previous two expressions imply

$$x_{ib} = \frac{\phi_{ib}\gamma_i}{\sum_{i=1}^{n}\phi_{ib}\gamma_i}\sum_{i=1}^{n} x_{ib},$$

or equivalently (since $v_i = \alpha\gamma_i$),

$$x_{ib} = \frac{\phi_{ib}v_i}{\sum_{i=1}^{n}\phi_{ib}v_i}\sum_{i=1}^{n} x_{ib} = \frac{\phi_{ib}v_i}{\sum_{i=1}^{n}\phi_{ib}v_i} z_b D_b, \tag{C.1.8}$$

where the last equality uses (5.7). Next, (5.6) implies

$$\sum_{i=1}^{n} r_b x_{ib} = RD_b.$$

Summing across banks,

$$\sum_{b=1}^{m}\sum_{i=1}^{n} r_b x_{ib} = R\sum_{b=1}^{m} D_b = RD.$$

The previous two expressions imply

$$D_b = \frac{\sum_{i=1}^{n} r_b x_{ib}}{\sum_{b=1}^{m}\sum_{i=1}^{n} r_b x_{ib}} D.$$

Substituting from (C.1.7),

$$D_b = \frac{\sum_{i=1}^{n}\chi\alpha\frac{p_j c_j}{\beta_j}\phi_{ib}\gamma_i}{\sum_{b=1}^{m}\sum_{i=1}^{n}\chi\alpha\frac{p_j c_j}{\beta_j}\phi_{ib}\gamma_i} D = \frac{\sum_{i=1}^{n}\phi_{ib}\gamma_i}{\sum_{b=1}^{m}\sum_{i=1}^{n}\phi_{ib}\gamma_i} D,$$

or equivalently (since $v_i = \alpha\gamma_i$),

$$D_b = \frac{\sum_{i=1}^n \phi_{ib} v_i}{\sum_{b=1}^m \sum_{i=1}^n \phi_{ib} v_i} D. \tag{C.1.9}$$

Defining the bank market share $s_b \equiv \frac{D_b}{D}$, we thus have

$$s_b = \frac{D_b}{D} = \frac{\sum_{i=1}^n \phi_{ib} v_i}{\sum_{b=1}^m \sum_{i=1}^n \phi_{ib} v_i}. \tag{C.1.10}$$

Moreover, substituting for D_b in (C.1.8), we get

$$x_{ib} = \frac{\phi_{ib} v_i}{\sum_{i=1}^n \phi_{ib} v_i} z_b \frac{\sum_{i=1}^n \phi_{ib} v_i}{\sum_{b=1}^m \sum_{i=1}^n \phi_{ib} v_i} D = \frac{\phi_{ib} v_i}{\sum_{b=1}^m \sum_{i=1}^n \phi_{ib} v_i} z_b D, \tag{C.1.11}$$

where $D = \sum_{i=1}^n w\ell_i = w$ by clearing on the market for working capital loans. Finally, notice that the denominator of the previous expressions satisfies

$$\sum_{b=1}^m \sum_{i=1}^n \phi_{ib} v_i = \sum_{i=1}^n \sum_{b=1}^m \phi_{ib} v_i = \sum_{i=1}^n v_i \sum_{b=1}^m \phi_{ib} = \sum_{i=1}^n v_i = \frac{\alpha}{1-\zeta(1-\alpha)},$$

where the result follows from $\sum_{b=1}^m \phi_{ib} = 1$ and from (C.1.5).

C.1.5 Proof of Proposition 2

First, substitute from the factor demand functions (C.1.6) and (C.1.11) into the production function (5.1) of sector i to get

$$\begin{aligned} q_i &= \left(\prod_{b=1}^m \ell_i^\alpha \prod_{j=1}^n q_{ij}^{(1-\alpha)\omega_{ij}} \right)^\eta = \left(w^{-\alpha} \prod_{b=1}^m x_{ib}^{\alpha\phi_{ib}} \prod_{j=1}^n q_{ij}^{(1-\alpha)\omega_{ij}} \right)^\eta \\ &= \left(w^{-\alpha} \prod_{b=1}^m \left[\frac{\phi_{ib} v_i}{\sum_{i=1}^n v_i} z_b D \right]^{\alpha\phi_{ib}} \prod_{j=1}^n \left[\zeta(1-\alpha)\omega_{ij} q_j \frac{v_i}{v_j} \right]^{(1-\alpha)\omega_{ij}} \right)^\eta, \end{aligned}$$

where $\sum_{i=1}^n v_i = \frac{\alpha}{1-\zeta(1-\alpha)}$. Taking logs,

$$\begin{aligned} \ln q_i = \eta \Big\{ &-\alpha w + \alpha \sum_{b=1}^m \phi_{ib} \left[\ln \phi_{ib} + \ln z_b + \ln v_i - \ln \alpha + \ln(1-\zeta(1-\alpha)) + \ln D \right] \\ &+ (1-\alpha) \sum_{j=1}^n \omega_{ij} \left[\ln(\zeta(1-\alpha)) + \ln \omega_{ij} + \ln q_j + \ln v_i - \ln v_j \right] \Big\}, \end{aligned}$$

where $D = \sum_{i=1}^{n} w\ell_i = w$ by clearing on the market for working capital loans. Reorganizing,

$$\ln q_i = \eta\Big\{\alpha\left[(\ln v_i - \ln\alpha + \ln(1-\zeta(1-\alpha)))\sum_{b=1}^{m}\phi_{ib} + \sum_{b=1}^{m}\phi_{ib}\left(\ln\phi_{ib} + \ln z_b\right)\right]$$
$$+ (1-\alpha)\left[(\ln(\zeta(1-\alpha)) + \ln v_i)\sum_{j=1}^{n}\omega_{ij} + \sum_{j=1}^{n}\omega_{ij}\left(\ln\omega_{ij} + \ln q_j - \ln v_j\right)\right]\Big\}.$$

As $\sum_{b=1}^{m}\phi_{ib} = 1$ and $\sum_{j=1}^{n}\omega_{ij} = 1$, and stacking over n sectors,

$$\mathbf{q} = \eta\Big\{\alpha\left[\overline{\mathbf{v}} - \mathbf{1}\ln\alpha + \mathbf{1}\ln(1-\zeta(1-\alpha)) + \boldsymbol{\Theta}\right]$$
$$+ (1-\alpha)\left[\overline{\mathbf{v}} + \mathbf{1}\ln(\zeta(\mathbf{1}-\alpha)) + \mathbf{W}\mathbf{q} - \mathbf{W}\overline{\mathbf{v}} + (\mathbf{W}\circ\overline{\mathbf{W}})\mathbf{1}\right]\Big\},$$

where vectors and matrices with bars are in logs, and where

$$\boldsymbol{\Theta} \equiv \begin{bmatrix} \sum_{b=1}^{m}\phi_{1b}\ln\left(\phi_{1b}z_b\right) \\ \vdots \\ \sum_{b=1}^{m}\phi_{nb}\ln\left(\phi_{nb}z_b\right) \end{bmatrix}.$$

Solving for $\mathbf{q}$,

$$\left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}\right]\mathbf{q} = \eta\Big\{\alpha\left[\overline{\mathbf{v}} - \mathbf{1}\ln\alpha + \mathbf{1}\ln(1-\zeta(1-\alpha)) + \boldsymbol{\Theta}\right]$$
$$+ (1-\alpha)\left[\overline{\mathbf{v}} + \mathbf{1}\ln(\zeta(\mathbf{1}-\alpha)) - \mathbf{W}\overline{\mathbf{v}} + (\mathbf{W}\circ\overline{\mathbf{W}})\mathbf{1}\right]\Big\},$$

or

$$\mathbf{q} = \left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}\right]^{-1}\eta\Big\{\alpha\left[\overline{\mathbf{v}} - \mathbf{1}\ln\alpha + \mathbf{1}\ln(1-\zeta(1-\alpha)) + \boldsymbol{\Theta}\right]$$
$$+ (1-\alpha)\left[\overline{\mathbf{v}} + \mathbf{1}\ln(\zeta(\mathbf{1}-\alpha)) - \mathbf{W}\overline{\mathbf{v}} + (\mathbf{W}\circ\overline{\mathbf{W}})\mathbf{1}\right]\Big\}.$$

Pre-multiplying the right-hand-side by $\mathbb{I} = \left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}\right]^{-1}\left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}\right]$,

$$\mathbf{q} = \left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}\right]^{-1}\mathbf{M}\eta\Big\{\alpha\left[\overline{\mathbf{v}} - \mathbf{1}\ln\alpha + \mathbf{1}\ln(1-\zeta(1-\alpha)) + \boldsymbol{\Theta}\right]$$
$$+ (1-\alpha)\left[\overline{\mathbf{v}} + \mathbf{1}\ln(\zeta(\mathbf{1}-\alpha)) - \mathbf{W}\overline{\mathbf{v}} + (\mathbf{W}\circ\overline{\mathbf{W}})\mathbf{1}\right]\Big\},$$

where

$$\mathbf{M} = \left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}\right]\left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}\right]^{-1}. \tag{C.1.12}$$

Recall the definition of the (transposed) influence vector in (C.1.4), $\mathbf{v}' = \alpha\beta'\left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}\right]^{-1}$. Hence, appropriate multiplication implies

$$\begin{aligned}\alpha\beta'\mathbf{q} = \mathbf{v}'\mathbf{M}\eta\Big\{&\alpha\left[\overline{\mathbf{v}} - \mathbf{1}\ln\alpha + \mathbf{1}\ln(1-\zeta(1-\alpha)) + \mathbf{\Theta}\right] \\ &+ (1-\alpha)\left[\overline{\mathbf{v}} + \mathbf{1}\ln(\zeta(\mathbf{1}-\alpha)) - \mathbf{W}\overline{\mathbf{v}} + (\mathbf{W}\circ\overline{\mathbf{W}})\mathbf{1}\right]\Big\},\end{aligned}$$

or

$$\begin{aligned}\beta'\mathbf{q} = \eta\mathbf{v}'\mathbf{M}\mathbf{\Theta} + \eta\mathbf{v}'\mathbf{M}\Big\{&\left[\overline{\mathbf{v}} - \mathbf{1}\ln\alpha + \mathbf{1}\ln(1-\zeta(1-\alpha))\right] \\ &+ \frac{(1-\alpha)}{\alpha}\left[\overline{\mathbf{v}} + \mathbf{1}\ln(\zeta(\mathbf{1}-\alpha)) - \mathbf{W}\overline{\mathbf{v}} + (\mathbf{W}\circ\overline{\mathbf{W}})\mathbf{1}\right]\Big\}.\end{aligned}$$

Defining

$$\Gamma_0 \equiv \eta\mathbf{v}'\mathbf{M}\Big\{\left[\overline{\mathbf{v}} - \mathbf{1}\ln\alpha + \mathbf{1}\ln(1-\zeta(1-\alpha))\right] + \frac{(1-\alpha)}{\alpha}\left[\overline{\mathbf{v}} + \mathbf{1}\ln(\zeta(\mathbf{1}-\alpha)) - \mathbf{W}\overline{\mathbf{v}} + (\mathbf{W}\circ\overline{\mathbf{W}})\mathbf{1}\right]\Big\},$$

the previous equation becomes

$$\beta'\mathbf{q} = \eta\mathbf{v}'\mathbf{M}\mathbf{\Theta} + \Gamma_0. \tag{C.1.13}$$

Next, recall that $v_i = \alpha\gamma_i = \alpha\beta_i\frac{q_i}{c_i}$. Taking logs, and expressing in vectorial form, we get

$$\mathbf{c} = \mathbf{q} - \overline{\mathbf{v}} + \mathbf{1}\ln\alpha + \ln\beta.$$

Pre-multiplying by β',

$$\beta'\mathbf{c} = \beta'\mathbf{q} - \beta'\overline{\mathbf{v}} + \ln\alpha - \beta'\ln\beta.$$

Finally, from (5.4), market clearing for final consumption goods implies

$$\ln Y = \beta'\mathbf{c}.$$

Putting the previous results together,

$$\begin{aligned}\ln Y &= \beta'\mathbf{q} - \beta'\overline{\mathbf{v}} + \ln\alpha - \beta'\ln\beta \\ &= \eta\mathbf{v}'\mathbf{M}\boldsymbol{\Theta} + \Gamma_0 - \beta'\overline{\mathbf{v}} + \ln\alpha - \beta'\ln\beta,\end{aligned}$$

where the last equality uses (C.1.13). Collecting in Γ the terms that are invariant to the balance sheet shocks z_b, we get

$$\ln Y = \eta\mathbf{v}'\mathbf{M}\boldsymbol{\Theta} + \Gamma, \tag{C.1.14}$$

where

$$\Gamma \equiv \Gamma_0 - \beta'\overline{\mathbf{v}} + \ln\alpha - \beta'\ln\beta.$$

Defining $\mathbf{d}' \equiv \mathbf{v}'\mathbf{M}$ and using (C.1.4) and (C.1.12), we have

$$\begin{aligned}\mathbf{d}' &= \mathbf{v}'\mathbf{M} \\ &= \alpha\beta'\left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}\right]^{-1}\left[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}\right]\left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}\right]^{-1} \\ &= \alpha\beta'\left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}\right]^{-1}. \end{aligned} \tag{C.1.15}$$

Hence,

$$\mathbf{d} = \alpha\left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}'\right]^{-1}\beta. \tag{C.1.16}$$

Using (C.1.15), equation (C.1.14) can be written as

$$\ln Y = \eta\mathbf{d}'\boldsymbol{\Theta} + \Gamma, \tag{C.1.17}$$

which is equivalent to

$$\ln Y = \Gamma + \eta\sum_{i=1}^{n}\left[d_i\sum_{b=1}^{m}\phi_{ib}\ln\left(\phi_{ib}z_b\right)\right]. \tag{C.1.18}$$

Characterization of the distortion influence vector. The following Lemma helps to further characterize the vector $\mathbf{d}'$ defined in (C.1.15).

Lemma 3 *Consider scalars α, β and quadratic matrix $\mathbf{A}$. Then,*

$$
\begin{aligned}
(\mathbb{I} - \alpha\mathbf{A})(\mathbb{I} - \beta\mathbf{A})^{-1} &= (\mathbb{I} - \alpha\mathbf{A})\left(\mathbb{I} + \beta\mathbf{A} + (\beta\mathbf{A})^2 + \dots\right) \\
&= \left(\mathbb{I} + \beta\mathbf{A} + (\beta\mathbf{A})^2 + \dots\right) - \alpha\mathbf{A}\left(\mathbb{I} + \beta\mathbf{A} + (\beta\mathbf{A})^2 + \dots\right) \\
&= \mathbb{I} + \beta\mathbf{A} + (\beta\mathbf{A})^2 + \dots - \alpha\mathbf{A} - \alpha\beta\mathbf{A}^2 - \alpha\beta^2\mathbf{A}^3 + \dots \\
&= \mathbb{I} + (\beta - \alpha)\mathbf{A} + (\beta^2 - \alpha\beta)\mathbf{A}^2 + (\beta^3 - \alpha\beta^2)\mathbf{A}^3 + \dots \\
&= \mathbb{I} + (\beta - \alpha)\mathbf{A} + (\beta - \alpha)\beta\mathbf{A}^2 + (\beta - \alpha)\beta^2\mathbf{A}^3 + \dots \\
&= (\beta - \alpha)\mathbb{I} + (\beta - \alpha)\mathbf{A} + (\beta - \alpha)\beta\mathbf{A}^2 + (\beta - \alpha)\beta^2\mathbf{A}^3 + \dots - (\beta - \alpha)\mathbb{I} + \mathbb{I} \\
&= \frac{(\beta - \alpha)}{\beta}\left[\mathbb{I} + \beta\mathbf{A} + \beta^2\mathbf{A}^2 + \beta^3\mathbf{A}^3 + \dots\right] - \frac{(\beta - \alpha)}{\beta}\mathbb{I} + (\beta - \alpha)\mathbb{I} - (\beta - \alpha)\mathbb{I} + \mathbb{I} \\
&= \frac{(\beta - \alpha)}{\beta}(\mathbb{I} - \beta\mathbf{A})^{-1} + \left(1 - \frac{(\beta - \alpha)}{\beta}\right)\mathbb{I} \\
&= \frac{(\beta - \alpha)}{\beta}(\mathbb{I} - \beta\mathbf{A})^{-1} + \frac{\alpha}{\beta}\mathbb{I} \\
&= \frac{\alpha}{\beta}\mathbb{I} + \frac{(\beta - \alpha)}{\beta}\left[\mathbb{I} + \beta\mathbf{A} + \beta^2\mathbf{A}^2 + \beta^3\mathbf{A}^3 + \dots\right].
\end{aligned}
$$

Using this Lemma, we have

$$
\begin{aligned}
\mathbf{M} = [\mathbb{I} - \zeta(1-\alpha)\mathbf{W}][\mathbb{I} - \eta(1-\alpha)\mathbf{W}]^{-1} &= \frac{(\eta(1-\alpha) - \zeta(1-\alpha))}{\eta(1-\alpha)}[\mathbb{I} - \eta(1-\alpha)\mathbf{W}]^{-1} + \frac{\zeta(1-\alpha)}{\eta(1-\alpha)}\mathbb{I} \\
&= \frac{\eta - \zeta}{\eta}[\mathbb{I} - \eta(1-\alpha)\mathbf{W}]^{-1} + \frac{\zeta}{\eta}\mathbb{I}
\end{aligned}
$$

and hence

$$
\begin{aligned}
\mathbf{d}' = \mathbf{v}'\mathbf{M} &= \mathbf{v}'[\mathbb{I} - \zeta(1-\alpha)\mathbf{W}][\mathbb{I} - \eta(1-\alpha)\mathbf{W}]^{-1} \\
&= \frac{\eta - \zeta}{\eta}\mathbf{v}'[\mathbb{I} - \eta(1-\alpha)\mathbf{W}]^{-1} + \frac{\zeta}{\eta}\mathbf{v}'\mathbb{I} \\
&= \frac{\eta - \zeta}{\eta}\mathbf{v}'\left[\mathbb{I} + \eta(1-\alpha)\mathbf{W} + (\eta(1-\alpha))^2\mathbf{W}^2 + (\eta(1-\alpha))^3\mathbf{W}^3 + \dots\right] + \frac{\zeta}{\eta}\mathbf{v}'\mathbb{I}, \\
&= \frac{\eta - \zeta}{\eta}\mathbf{v}'\left[\eta(1-\alpha)\mathbf{W} + (\eta(1-\alpha))^2\mathbf{W}^2 + (\eta(1-\alpha))^3\mathbf{W}^3 + \dots\right] + \mathbf{v}'\mathbb{I},
\end{aligned}
$$

where the third line simply expands $[\mathbb{I} - \eta(1-\alpha)\mathbf{W}]^{-1}$. Next, define vector δ as the deviation of vector $\mathbf{d}$ from the influence vector $\mathbf{v}$,

$$\delta \equiv \mathbf{d} - \mathbf{v}, \tag{C.1.19}$$

so that

$$
\begin{aligned}
\delta' &= \mathbf{d}' - \mathbf{v}' \\
&= \frac{\eta-\zeta}{\eta}\mathbf{v}'\left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}\right]^{-1} + \frac{\zeta-\eta}{\eta}\mathbf{v}'\mathbb{I} \\
&= \frac{\eta-\zeta}{\eta}\mathbf{v}'\left[\mathbb{I} + \eta(1-\alpha)\mathbf{W} + (\eta(1-\alpha))^2\mathbf{W}^2 + (\eta(1-\alpha))^3\mathbf{W}^3 + \dots\right] + \frac{\zeta-\eta}{\eta}\mathbf{v}'\mathbb{I} \\
&= \frac{\eta-\zeta}{\eta}\mathbf{v}'\left[\eta(1-\alpha)\mathbf{W} + (\eta(1-\alpha))^2\mathbf{W}^2 + (\eta(1-\alpha))^3\mathbf{W}^3 + \dots\right]. \qquad \text{(C.1.20)}
\end{aligned}
$$

By Lemma 1, $\eta < \zeta$. Since $\alpha < 1$ and the input-output matrix $\mathbf{W}$ is non-negative, it follows that vector δ contains only non-positive entries. Hence,

$$
\sum_{i=1}^{n} d_i \leq \sum_{i=1}^{n} v_i = \frac{\alpha}{1-\zeta(1-\alpha)}, \qquad \text{(C.1.21)}
$$

where the expression for $\sum_{i=1}^{n} v_i$ comes from (C.1.5).

C.1.6 Proof of Proposition 3

Recall (C.1.18),

$$
\ln Y = \Gamma + \eta \sum_{i=1}^{n}\left[d_i \sum_{b=1}^{m} \phi_{ib} \ln\left(\phi_{ib} z_b\right)\right],
$$

so that

$$
var[\ln Y] = var\left\{\Gamma + \eta \sum_{i=1}^{n}\left[d_i \sum_{b=1}^{m} \phi_{ib} \ln\left(\phi_{ib} z_b\right)\right]\right\}.
$$

Since Γ is composed of constants and η is a parameter, we have

$$
\begin{aligned}
var[\ln Y] &= \eta^2 var\left\{\sum_{i=1}^{n}\left[d_i \sum_{b=1}^{m} \phi_{ib} \ln\left(\phi_{ib} z_b\right)\right]\right\} \\
&= \eta^2 var\left\{\sum_{b=1}^{m}\sum_{i=1}^{n} d_i \phi_{ib} \ln(\phi_{ib} z_b)\right\} \\
&= \eta^2 \sum_{b=1}^{m} var\left\{\sum_{i=1}^{n} d_i \phi_{ib} \ln(\phi_{ib} z_b)\right\},
\end{aligned}
$$

where the last equality follows from the fact that the shocks z_b are independent across banks b. However, given the input-output network structure embodied in $\mathbf{W}$ (and relevant here via the vector $\mathbf{d}$), the propagation of shocks implies that there is no independence across intermediate good sectors. The variance expression therefore needs to take into account the covariances across sectors i. Therefore,

$$var[\ln Y] = \eta^2 \left(\sum_{b=1}^{m} \left\{ \sum_{i=1}^{n} var\left[d_i \phi_{ib} \ln(\phi_{ib} z_b)\right] \right\} + 2 \sum_{b=1}^{m} \sum_{i,j:i<j} cov\left[d_i \phi_{ib} \ln(\phi_{ib} z_b), d_j \phi_{jb} \ln(\phi_{jb} z_b)\right] \right).$$

According to the properties of the variance and covariance operators and recalling that d_i and ϕ_{ib} are constant, we can express the previous equation as

$$\begin{aligned}
var[\ln Y] = \eta^2 \sum_{b=1}^{m} & \left\{ \sum_{i=1}^{n} d_i^2 \phi_{ib}^2 var\left[\ln(\phi_{ib}) + \ln(z_b)\right] \right\} \\
& + 2\eta^2 \sum_{b=1}^{m} \sum_{i,j:i<j} d_i \phi_{ib} d_j \phi_{jb} cov\left[\ln(\phi_{ib}) + \ln(z_b), \ln(\phi_{jb}) + \ln(z_b)\right] \\
& = \eta^2 \left(\sum_{b=1}^{m} \left\{ \sum_{i=1}^{n} d_i^2 \phi_{ib}^2 var\left[\ln(z_b)\right] \right\} + 2 \sum_{b=1}^{m} \sum_{i,j:i<j} d_i \phi_{ib} d_j \phi_{jb} cov\left[\ln(z_b), \ln(z_b)\right] \right) \\
& = \eta^2 \left(\sum_{b=1}^{m} \left\{ \sum_{i=1}^{n} d_i^2 \phi_{ib}^2 var\left[\ln(z_b)\right] \right\} + 2 \sum_{b=1}^{m} \sum_{i,j:i<j} d_i \phi_{ib} d_j \phi_{jb} var\left[\ln(z_b)\right] \right) \\
& = \eta^2 \sum_{b=1}^{m} \left\{ var\left[\ln(z_b)\right] \right\} \left[\sum_{i=1}^{n} d_i^2 \phi_{ib}^2 + 2 \sum_{i,j:i<j} d_i \phi_{ib} d_j \phi_{jb} \right] \\
& = \eta^2 \sum_{b=1}^{m} \left\{ var\left[\ln(z_b)\right] \right\} \left[\sum_{i,j} d_i \phi_{ib} d_j \phi_{jb} \right].
\end{aligned}$$

Thus, defining $\sigma_b^2 \equiv var\left[\ln(z_b)\right]$, we have

$$var[\ln Y] = \eta^2 \sum_{b=1}^{m} \sigma_b^2 \left[\sum_{i,j} d_i \phi_{ib} d_j \phi_{jb} \right]. \tag{C.1.22}$$

If all banks have the same distribution of shocks, $\sigma_b = \sigma$, and these are independent, we have

$$var[\ln Y] = \sigma^2 \eta^2 \sum_{b=1}^{m} \sum_{i,j}^{n,n} d_i \phi_{ib} d_j \phi_{jb} = \sigma^2 \eta^2 \sum_{b=1}^{m} \left(\sum_{i=1}^{n} d_i \phi_{ib} \sum_{j=1}^{n} d_j \phi_{jb} \right). \tag{C.1.23}$$

Next, recall from (C.1.10) the definition of the bank market share,

$$s_b = \frac{D_b}{D} = \frac{\sum_{i=1}^{n} \phi_{ib} v_i}{\sum_{b=1}^{m} \sum_{i=1}^{n} \phi_{ib} v_i} = \frac{1 - \zeta(1-\alpha)}{\alpha} \sum_{i=1}^{n} \phi_{ib} v_i,$$

and from (C.1.19) the definition of vector $\delta = \mathbf{d} - \mathbf{v}$. The variance expression in (C.1.23) can then be rewritten as

$$
\begin{aligned}
var[\ln Y] &= \sigma^2\eta^2 \sum_{b=1}^{m} \left(\sum_{i=1}^{n} d_i \phi_{ib} \sum_{j=1}^{n} d_j \phi_{jb} \right) \\
&= \sigma^2\eta^2 \sum_{b=1}^{m} \left(\sum_{i=1}^{n} (v_i + \delta_i)\, \phi_{ib} \sum_{j=1}^{n} (v_j + \delta_j)\, \phi_{jb} \right) \\
&= \sigma^2\eta^2 \sum_{b=1}^{m} \left(\sum_{i=1}^{n} v_i \phi_{ib} \sum_{j=1}^{n} v_j \phi_{jb} + \sum_{i=1}^{n} v_i \phi_{ib} \sum_{j=1}^{n} \delta_j \phi_{jb} + \sum_{i=1}^{n} \delta_i \phi_{ib} \sum_{j=1}^{n} v_j \phi_{jb} + \sum_{i=1}^{n} \delta_i \phi_{ib} \sum_{j=1}^{n} \delta_j \phi_{jb} \right) \\
&= \sigma^2\eta^2 \sum_{b=1}^{m} \left(\left(\frac{\alpha}{1-\zeta(1-\alpha)} \right)^2 s_b s_b + \frac{\alpha}{1-\zeta(1-\alpha)} s_b \sum_{j=1}^{n} \delta_j \phi_{jb} + \sum_{i=1}^{n} \delta_i \phi_{ib} \frac{\alpha}{1-\zeta(1-\alpha)} s_b + \sum_{i=1}^{n} \delta_i \phi_{ib} \sum_{j=1}^{n} \delta_j \phi_{jb} \right) \\
&= \sigma^2\eta^2 \sum_{b=1}^{m} \left(\left(\frac{\alpha}{1-\zeta(1-\alpha)} \right)^2 s_b^2 + \frac{\alpha}{1-\zeta(1-\alpha)} s_b \left(\sum_{j=1}^{n} \delta_j \phi_{jb} + \sum_{i=1}^{n} \delta_i \phi_{ib} \right) + \sum_{i=1}^{n} \delta_i \phi_{ib} \sum_{j=1}^{n} \delta_j \phi_{jb} \right) \\
&= \sigma^2\eta^2 \sum_{b=1}^{m} \left(\left(\frac{\alpha}{1-\zeta(1-\alpha)} \right)^2 s_b^2 + 2 \frac{\alpha}{1-\zeta(1-\alpha)} s_b \sum_{i=1}^{n} \delta_i \phi_{ib} + \left(\sum_{i=1}^{n} \delta_i \phi_{ib} \right)^2 \right) \\
&= \sigma^2\eta^2 \sum_{b=1}^{m} \left(\left(\frac{\alpha}{1-\zeta(1-\alpha)} \right) s_b + \left(\sum_{i=1}^{n} \delta_i \phi_{ib} \right) \right)^2, \qquad \text{(C.1.24)}
\end{aligned}
$$

where s_b is defined in (C.1.10) and δ_i is an element of vector δ defined in (C.1.20),

$$\delta' = \frac{\eta - \zeta}{\eta} \mathbf{v}' \left[\eta(1-\alpha)\mathbf{W} + (\eta(1-\alpha))^2 \mathbf{W}^2 + (\eta(1-\alpha))^3 \mathbf{W}^3 + \dots \right].$$

To the first-order, we thus have

$$\delta' \approx (\eta - \zeta)(1-\alpha)\mathbf{v}'\mathbf{W},$$

implying

$$\delta_i \approx (\eta - \zeta)(1-\alpha) \sum_{j=1}^{n} v_j \omega_{ji} \le 0,$$

where the inequality follows since $\eta < \zeta$, $\alpha < 1$ and all entries of the input-output matrix $\mathbf{W}$ are non-negative. Generically (that is, when sector i is relevant at all as a supplier of intermediate inputs), the inequality is strict, $\delta_i < 0$, since at least one $\omega_{ji} > 0$ when sector i supplies intermediate inputs to other sectors.

Table C.1.1: Sector Classification breakdown in the economy

Sector Classification
Agriculture(Agric)
Production
Farming (Crops, Livestock and Poultry)
Fishing
Forestry
Other
Processing & Marketing
O/w Marketing
Mining and Quarrying(Mining)
Crude Petroleum & Natural Gas
Other Mining & Quarrying
Manufacturing(manufacturing)
Food, Beverages and Tobacco
Textiles, Apparel and Leather
Wood, Wood Products & Furniture
Paper, Paper Products, Printing & Publishing
Chemicals, Pharmaceuticals, Plastic and Rubber Products
Basic and Fabricated Non-Metal and Metal Products
Building & Construction Materials.
Other Manufacturing Industries
Trade(Trade)
Wholesale Trade
Retail
Restaurants and Hotels
Exports
Imports
Re-Exports
Transport and Communication(Transport)
Land (Road & Rail) Transport
Water Transport

Table C.1.1: Sector Classification breakdown in the economy

Sector Classification
Air Transport
Travel Agencies
Postal & Courier Services
Telecommunications
Electricity and Water(Electric)
Electricty, Lighting & Power
Water, Water Works & Supply
Building, Mortgage, Construction and Real Estate(Build)
Mortgage
Residential Mortgages
Commercial Mortgages
Land Purchase
Road Construction and Mantainance
General Construction Contractors e.g. Building/Construction Companies
Specialised Contractors e.g. Plumbers, Roof Repair, Electrical Contractors etc
Property Developers, Estate Agents and Letting Agents
Business Services(Business)
Working Capital
Other
Community, Social & Other Services(Social)
Education Services
Health Services
Membership Organisations, Community Development
Recreational, Cultural and Sporting Sevices
International Organisations
Other Services(Others)

C.1.7 Analytical results for Section 5.3.1

From Proposition 3, aggregate volatility is given by

$$var[\ln Y] = \sigma^2\eta^2 \sum_{b=1}^{m} \left(\sum_{i=1}^{n} d_i \phi_{ib} \sum_{j=1}^{n} d_j \phi_{jb} \right).$$

Considering the case with $n = 2$ sectors and $m = 2$ banks, we have

$$\begin{aligned}
var[\ln Y] &= \sigma^2\eta^2 \sum_{b=1}^{2} \left(\sum_{i=1}^{2} d_i \phi_{ib} \sum_{j=1}^{2} d_j \phi_{jb} \right) \\
&= \sigma^2\eta^2 \sum_{b=1}^{2} \sum_{i=1}^{2} d_i \phi_{ib} \left[d_1\phi_{1b} + d_2\phi_{2b} \right] \\
&= \sigma^2\eta^2 \sum_{b=1}^{2} d_1\phi_{1b} \left[d_1\phi_{1b} + d_2\phi_{2b} \right] + d_2\phi_{2b} \left[d_1\phi_{1b} + d_2\phi_{2b} \right] \\
&= \sigma^2\eta^2 d_1\phi_{11} \left[d_1\phi_{11} + d_2\phi_{21} \right] + \sigma^2\eta^2 d_2\phi_{21} \left[d_1\phi_{11} + d_2\phi_{21} \right] \\
&+ \sigma^2\eta^2 d_1\phi_{12} \left[d_1\phi_{12} + d_2\phi_{22} \right] + \sigma^2\eta^2 d_2\phi_{22} \left[d_1\phi_{12} + d_2\phi_{22} \right].
\end{aligned}$$

Since for sector 1 $\phi_{12} = 1 - \phi_{11}$ and for sector $\phi_{21} = 1 - \phi_{22}$,

$$\begin{aligned}
\frac{1}{\sigma^2\eta^2} var[\ln Y] &= d_1\phi_{11} \left[d_1\phi_{11} + d_2(1-\phi_{22}) \right] + d_2(1-\phi_{22}) \left[d_1\phi_{11} + d_2(1-\phi_{22}) \right] \\
&+ d_1(1-\phi_{11}) \left[d_1(1-\phi_{11}) + d_2\phi_{22} \right] + d_2\phi_{22} \left[d_1(1-\phi_{11}) + d_2\phi_{22} \right] \\
&= 2\phi_{11}^2 d_1^2 + 2\phi_{22}^2 d_2^2 - 4\phi_{11}\phi_{22} d_1 d_2 - 2\phi_1(d_1^2 - d_1 d_2) - 2\phi_{22}(d_2^2 - d_1 d_2) + d_1^2 + d_2^2.
\end{aligned}$$

As ϕ_{11} and ϕ_{22} are independent (but $0 \leq \phi_{11}, \phi_{22} \leq 1$), the first-order conditions for an interior extremum are

$$\begin{aligned}
4d_1^2\phi_{11} - 4\phi_{22} d_1 d_2 - 2(d_1^2 - d_1 d_2) = 0 \\
4d_2^2\phi_{22} - 4\phi_{11} d_1 d_2 - 2(d_2^2 - d_1 d_2) = 0,
\end{aligned}$$

or equivalently,

$$\begin{bmatrix} d_1^2 & -d_1 d_2 \\ -d_1 d_2 & d_2^2 \end{bmatrix} \begin{bmatrix} \phi_{11} \\ \phi_{22} \end{bmatrix} = \frac{1}{2} \begin{bmatrix} d_1^2 - d_1 d_2 \\ d_2^2 - d_1 d_2 \end{bmatrix}.$$

As the determinant is zero, the equations are either dependent or incompatible. In fact, the solution is given by any ϕ_{22} satisfying

$$\phi_{22} = \frac{d_1}{d_2}\phi_{11} - \frac{d_1^2 - d_1 d_2}{2d_1 d_2} = \frac{d_1}{d_2}\phi_{11} - \frac{d_1 - d_2}{2d_2} \tag{C.1.25}$$

subject to the restriction $0 \leq \phi_{11}, \phi_{22} \leq 1$.

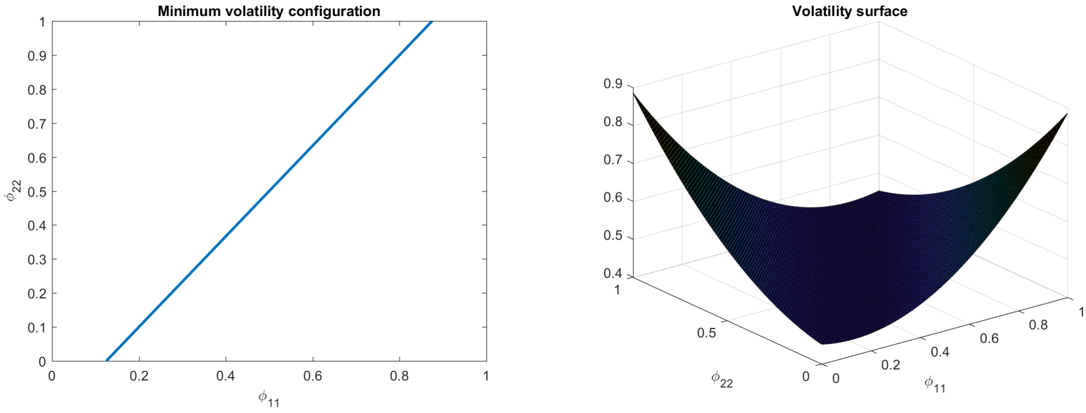
As an example, consider the case where $\beta' = [0.5, 0.5]$ and

$$\mathbf{W} = \begin{bmatrix} 1 & 0 \\ 0.5 & 0.5 \end{bmatrix},$$

so that

$$\mathbf{d} = \alpha \left[\mathbb{I} - \eta(1-\alpha)\mathbf{W}'\right]^{-1} \beta \approx [0.5378, 0.4034]'.$$

Notice that $\phi_{11} = \phi_{22} = 0.5$ is a solution. That is, although the input-output network is asymmetric, the set of volatility minimizing configurations for financial intermediation includes the symmetric one where both sectors have equal funding shares from both banks. Going away from the symmetric configuration, as the high-distortion influence sector 1 starts to concentrate its funding on bank 1 (higher ϕ_{11}), the low-distortion influence sector 2 needs to accommodate this by increasing its funding from bank 2 more than proportionately (higher ϕ_2); mathematically, this is the consequence of the fact that $d_1 > d_2$. Notice also that the constraint $0 \leq \phi_{22} \leq 1$ requires $\frac{d_1 - d_2}{2d_1} \leq \phi_{11} \leq \frac{d_1 + d_2}{2d_1}$. That is, the high-distortion influence sector 1 cannot fully concentrate its borrowing on one bank. Figure A.1 below plots the minimum volatility configuration between ϕ_{11} and ϕ_{22} implied by equation (C.1.25) and the volatility surface for all feasible combinations of ϕ_{11} and ϕ_{22}.



(a) Minimum volatility configuration (b) Volatility surface

Figure C.1.1: Configuration of financial intermediation in the example economy

C.2 Empirical illustration and quantitative results

C.2.1 Financial intermediation in Uganda

Although Uganda's recent economic history has seen significant financial development, most indicators of financial development are still low by international standards. Similar to most low income countries, financial market depth in general, and the size of the banking system in particular, are smaller – in terms of domestic credit relative to GDP – and less open – in terms of de iure and de facto measures of financial integration – in Uganda than their counterparts in developed countries (Abuka et al., 2019).

The informal economy in Uganda is large, with estimates in the range of 30 to 40% of GDP (La Porta and Shleifer, 2014). Informality is thus important both in the financial and non-financial sectors. Importantly, however, this informal activity remains largely disconnected from the formal economy: There are only very few transitions of firms between the informal and the formal sectors. Moreover, the interaction between trading partners and on credit markets is characterized by substantial self-enforcement mechanisms (e.g. through the operation of the tax system; de Paula and Scheinkman, 2010), which induce a tendency of separation between formal and informal activity.[2] LaPorta and Shleifer (2008, 2014) thus advocate a dual

[2]LaPorta and Shleifer (2008, 2014) report that, in firm-level survey data across a number of developing countries, only two percent of informal firms sell their output to large (formal) firms.

view of informality. Accordingly, informal activity on both financial and non-financial markets is separate from the formal economy. In particular, access to formal finance is limited to firms which themselves operate as formal, registered businesses.

With this in mind, Table B.1 provides some statistics relating to formal finance in Uganda from the Global Financial Development Database.

	2010	2011	2012	2013	2014	2015	2016	2017
(1) Private credit by financial sector to GDP (%)	11.23	12.29	12.31	12.34	12.67	13.44	13.28	12.37
(2) Private credit by deposit money banks to GDP (%)	10.86	11.86	11.84	11.84	12.18	12.89	12.67	11.81
(3) Bank dependence [(2)/(1)]	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95
(4) Total loans to total deposits (%)	46.41	52.26	50.70	48.53	47.47	49.37	48.28	44.20
(5) Total loans to total assets (%)	65.34	73.84	74.96	73.42	70.48	73.14	70.67	64.41
(6) Deposit dependence [(5)/(4)]	0.71	0.71	0.68	0.66	0.67	0.68	0.68	0.69
(7) Bank concentration (largest 3 banks, %)			43.47	41.00	39.10	37.63	37.98	42.68
(8) Bank concentration (largest 5 banks, %)			59.02	56.84	55.45	54.27	54.84	61.20

Source: Bank of Uganda, Uganda Bureau of Statistics and authors' computations.
Financial sector defined as deposit money banks and other financial institutions.

Table C.2.1: Financial development and banking in Uganda (2010-2017)

Formal financial sector credit to the private sector has increased from 11.2% of GDP in 2010 to 12.4% of GDP in 2017. The overwhelming share of this is actually originated in the banking system, whose credit volume to the private sector expanded from 10.9% to 11.8% of GDP over the same period. The Ugandan economy is thus characterized by significant *bank dependence*, with an average of 96% of private sector credit coming from banks. The banking system itself is strongly dependent on deposit funding. Deposits as a share of GDP range between 14.6% and 16.9% (Global Financial Development Database, 2018), and they are by far the most important source of funding for bank assets. Indeed, *deposit dependence*, calculated as the fraction of bank deposits relative to assets, was at 71% in 2010 and at 69% in 2017. By contrast, the availability of wholesale funding is very limited; with a ratio of interbank borrowing to total deposits in the banking system at only 2% in 2017 (Bank of Uganda Financial Stability Report, 2017), the interbank market is weak.

While Uganda still has a substantial informal financial sector, the formal banking sector is well-established and adequately capitalized,[3] though with a relatively small number of banks. It currently comprises 25 (private) banks and is characterized by a *high degree of concentration*. The market share (in terms of total assets) controlled by the three largest banks accounted for more about 40% in 2017, and the combined balance sheet of the five largest banks made up more than 60% of the overall assets held in the banking system.

[3]In 2017, the average tier one capital adequacy ratio and total capital adequacy ratio were 21.4% and 23.6%, respectively (Bank of Uganda Financial Stability Report, 2017).

C.2.2 Bank-level volatility

Figure C.2.1 plots the standard deviation of the bank-level supply shocks ς_b estimated in (5.21) against the banks' market share. There is no evident pattern indicating a systematic effect of bank size on volatility. A linear regression results in a slope estimate of -0.01 estimated without significance ($p = 0.28$). We thus assume a uniform volatility at the level of the cross-sectional average, $\sigma_b = \sigma = 0.3313$.

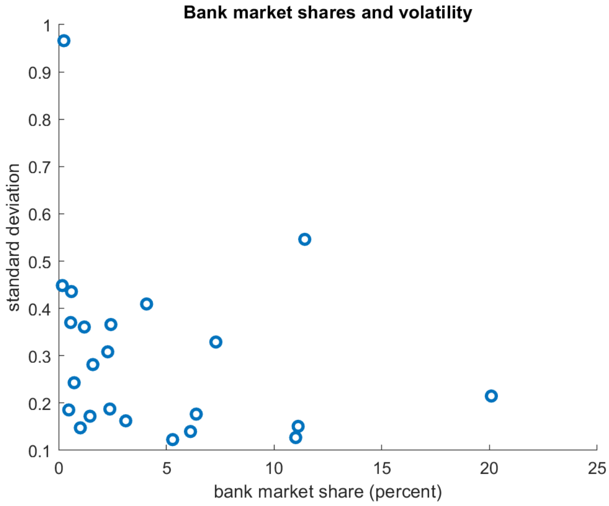
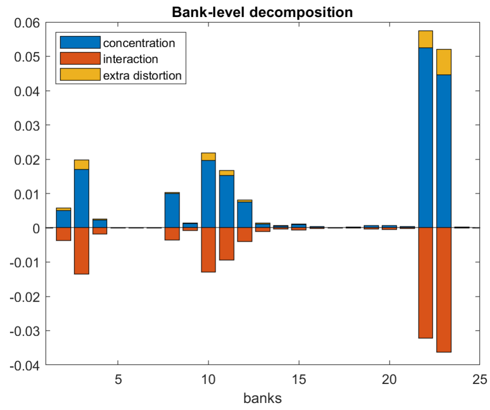
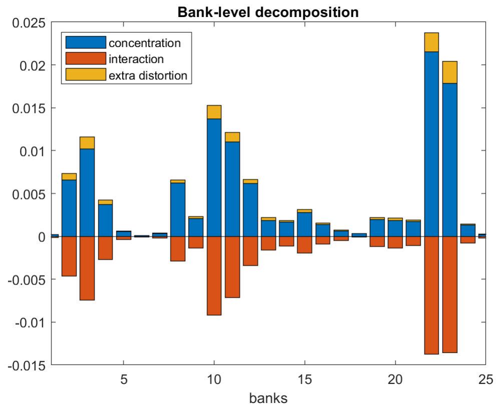


Figure C.2.1: Bank market shares and volatility

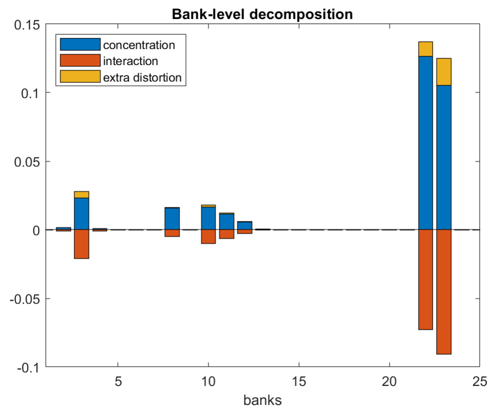
C.2.3 Bank-level decomposition under intermediation counterfactuals



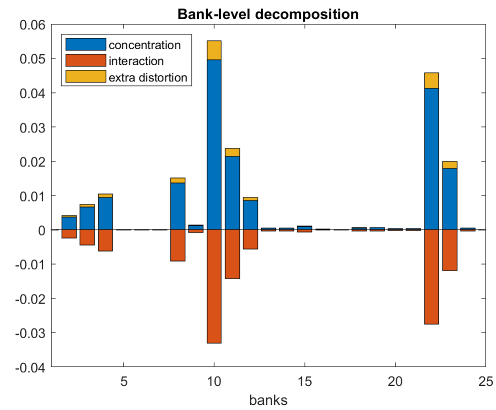
(a) Empirical data



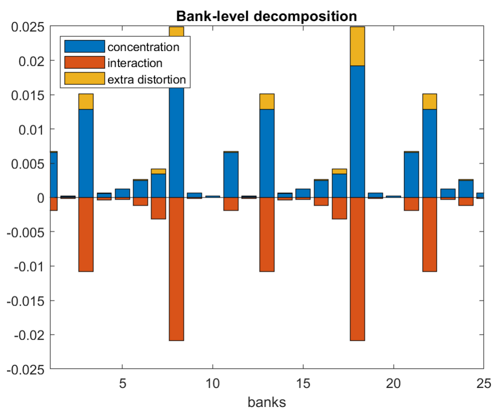
(b) Low concentration



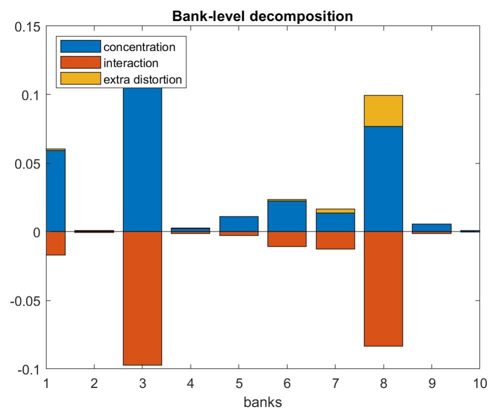
(c) High concentration



(d) Diversification



(e) Specialization $m = 25$



(f) Specialization $m = 10$

Figure C.2.2: Contribution to aggregate volatility: bank-level decomposition.