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Bank Network Analysis in the ECCU

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Abstract

This paper applies network analysis to assess the extent of systemic vulnerabilities in the ECCU banking system. It includes two sets of illustrative stress tests. First, solvency and liquidity shocks to each individual bank and the impact on other banks in the network through their biltareal net asset exposures. Second, country and region-wide tail shocks to GDP affecting capital and liquidity of all banks in the shocked jurisdictions, followed by the rippling effects through the regional network. The results identify systemic institutions that merit hightened attention by the regulator, as determined by the degree of connectivity with the rest of the system, and the extent to which they are vulnerable to the failure of other banks.

JEL Classification Numbers: Financial Surveillance, Network Analysis, Cross-Border Financial Linkages

Keywords: F34, G21

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I. INTRODUCTION

The Eastern Caribbean Currency Union (ECCU) financial system is large relative to the size of their economies, and is dominated by banks, with assets ranging from 100 to near 300 percent of GDP, depending on the jurisdiction. Moreover, ECCU commercial banks display significant linkages within- and across jurisdictions, partly driven by the joint operating environment within a single currency and a shared central bank. While some foreign institutions are linked to the same parent entity, many banks are also interconnected through interbank lending.

Following the global financial crisis (GFC), ECCU banks experienced substantial financial distress, as reflected by high non-performing loans. At end-2017Q3, banks' NPLs stood at 11 percent of total loans. While well above the region's tolerance limit of 5 percent, NPLs had declined significantly from the peak of 19 percent in mid-2014. Provisioning, however, has remained insufficient. Limited availability of bankable projects, coupled with tight underwriting standards – a legacy of the GFC – has restrained credit growth. This, combined with robust deposit growth propelled excess liquidity in the banking sector.

This paper uses bilateral net asset exposures in ECCU locally-incorporated banking system to analyze the risk of contagion or shock propagation among banks.[1] The ECCU include six independent states: Antigua and Barbuda, The Commonwealth of Dominica, Grenada, St. Kitts and Nevis, Saint Lucia and St. Vincent and the Grenadines, and two British Overseas Territories: Anguilla and Montserrat. ECCU jurisdictions share a common central bank – the Eastern Caribbean Central Bank (ECCB)[2] – and a common currency which has been pegged to the U.S. dollar since 1976.[3]

The key risk under analysis is the extent to which the failure of an individual bank could trigger a chain of bank failures in the system through inter-bank bilateral exposures. Two types of shocks are run based on the methodology in Espinosa-Vega and Sole (2010). First, a lending (asset) shock, which reduces the value of bank's portfolio into insolvency. The simulations then look at the propagation of that shock in the banking system as determined by their bilateral net exposures. Potentially, a chain of other bankruptcies can occur as exposed institutions are defaulted by the failing bank and thus suffer an asset and capital loss. Second, the analysis also includes a liquidity (liability) shock, which could take place in a scenario of systemic liquidity pressures triggered by the originating bankruptcy, which then leads to asset fire sales causing further capital losses, and potentially additional bankruptcies.

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[1] Preference given to "net" rather than "gross" bilateral exposures due to data limitations on "gross" figures.

[2] The ECCB is responsible for liquidity management, maintenance of the payment system, and banking sector regulation and supervision. It was established on October 1, 1983, as part of the Treaty of Basseterre establishing the Organization of Eastern Caribbean States.

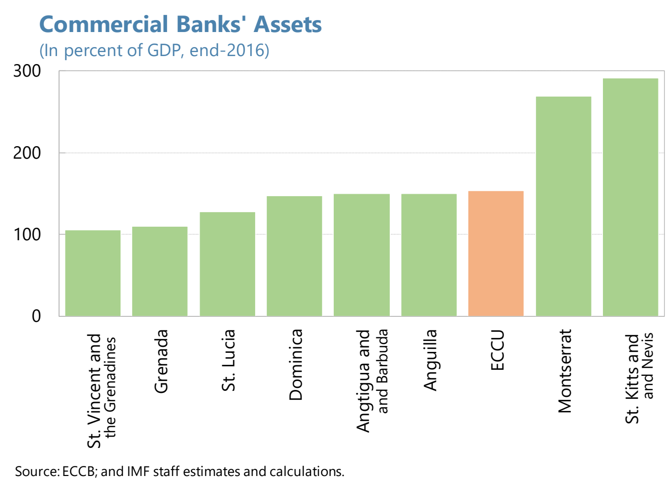
[3] Currently at XCD$2.70=US$1. Prior to that, the countries operated under the British Caribbean Currency Board since 1950, and started sharing their currency, the Eastern Caribbean Dollar (EC$) in 1965 under the Eastern Caribbean Currency Authority, with a peg to the British Pound at EC$4.80=GBP1.

The simulations are performed in two steps. First, an individual-bank idiosyncratic shock, which entails a shock to a bank's asset value. Second, a tail macroeconomic shock with a decline in output and an increase in interest rates. In the simulation, this shock affects asset values and capital in all banks in the affected country, and then spreads to other banks in the regional system through the network interconnections. The latter scenario is informed by empirical estimates that capture the impact of a tail shock on main macroeconomic indicators. These shocks are relevant given high output volatility, small size, and undiversified production base—characteristic in ECCU economies. Finally, a region-wide tail shock is also presented to test the resilience to extreme external shocks affecting all countries.

The rest of the paper proceeds in five sections. Section II presents background information with indicators that showcase the financial conditions of the ECCU banks. Section III describes the methodology of the network analysis. Section IV presents the simulation results. Section V concludes.

II. The State of the ECCU Banking Sector

The ECCU financial systems are large relative to the size of their economies, and continue to be dominated by banks (text chart). In *St. Kitts and Nevis*, for instance, banking sector assets amounted to nearly 300 percent of GDP at end-2016, and constituted ¼ of the ECCU banking sector. In *Antigua and Barbuda*, and *Saint Lucia*, commercial banks' assets added up to 150 and 130 percent of GDP, respectively. Each of these two countries individually contributed about 20 percent to the total ECCU banking sector. Overall, the ECCU banking sector size is about 150 percent of GDP. In mid-2017, the ECCU banking sector comprised 35 institutions, 17 of which were locally incorporated banks, constituting about 53 percent of total assets. The rest, 18 entities, constituted foreign incorporated banks, mainly headquartered in Canada.



ECCU commercial banks display significant linkages within- and across jurisdictions, partly driven by the joint operating environment within a single currency and a shared central bank. Interbank exposures relative to the size of their capital, however, appear to have diminished over time. While some foreign institutions are linked to the same parent entity, many banks are also interconnected through interbank lending. Relative to their capital, interbank exposures of the locally incorporated institutions have declined in recent years.[4] This is

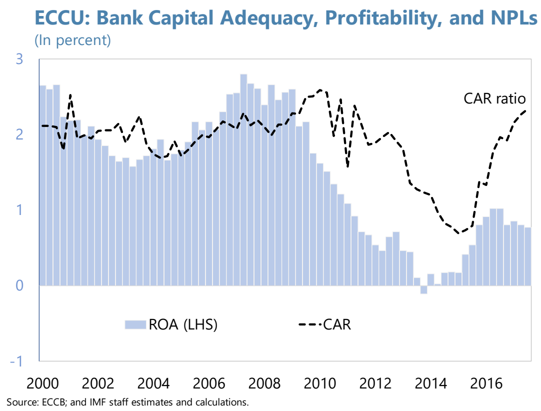
[4] Capital here is measured as total qualifying capital above the regulatory minimum of 8 percent, and excluding net NPLs. Thus, lower NPLs and higher provisioning rates have also helped diminish interbank exposures.

primarily attributed to the increased capital accumulation, and to some extent to higher excess liquidity and lesser demand for interbank loans (Figure 1).[5] The evolution of network analysis results are presented in Appendix 2.

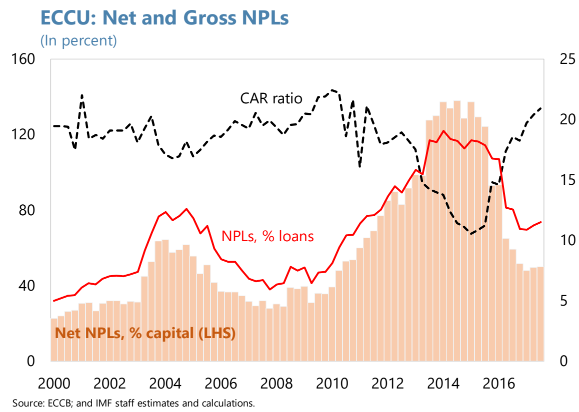
The high level of NPLs in most banks highlights the importance of assessing risk and monitoring progress on banks' capitalization. As of 2017Q3, banks' NPLs stood at 11 percent of total loans. While well above the region's tolerance limit of 5 percent, NPLs had declined significantly from the peak of 19 percent in mid-2014. Provisioning, however, has remained insufficient. Limited availability of bankable projects, coupled with tight underwriting standards – a legacy of the GFC – has restrained credit growth. This, combined with robust deposit growth propelled excess liquidity in the banking sector. Operating expenses also remain a drag on bank performance.

Figure 1. ECCU Commercial Banks: Financial Soundness Indicators

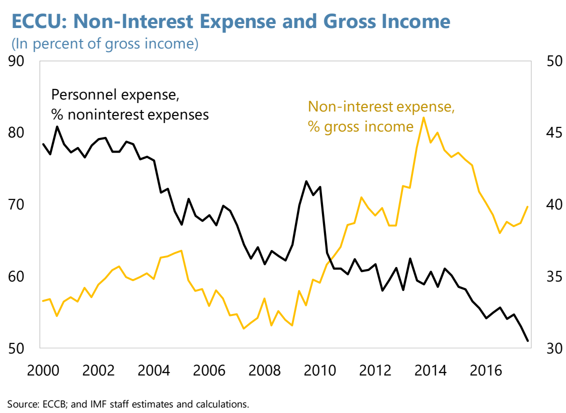
ECCU commercial bank capital ratio increased in recent years, but profitability remains low.



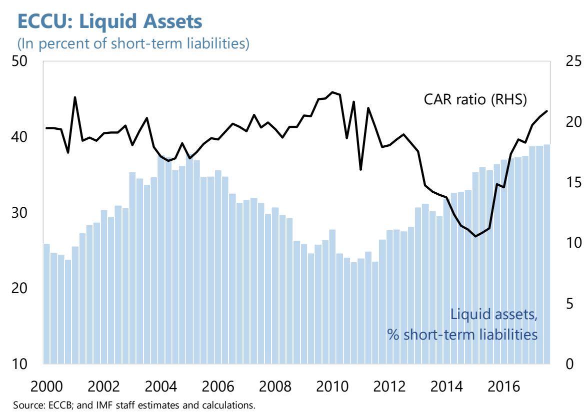
NPLs have come down recently, but due to insufficient provisioning, net NPLs in percent of capital remain elevated.



Banks' operating expenses remain elevated.



Meanwhile liquidity is at an all-times high.

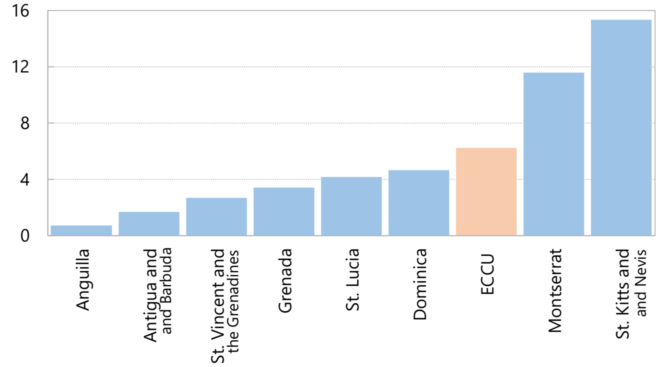


[5] Commercial banks' capital position is some instances improved partly in response to higher requirement of paid-in capital of the new Banking Act of the ECCU (2015).

Bank exposures vis-à-vis other entities also remain significant. Commercial banks hold a sizable portion of ECCU sovereign debt, which in turn strengthens the sovereign-bank nexus. At 16 and 12 percent of total assets, *St. Kitts and Nevis* and *Montserrat*, respectively, hold the largest share of ECCU sovereign debt relative to the size of their assets (text chart). Tight linkages also exist between commercial banks and other non-bank financial institutions (NBFI), such as credit unions, insurance companies, and pension funds (Alleyne and others, 2017).

Sovereign-Bank Nexus[1]

(Percent of total assets, end-2016)



Source: ECCB; and IMF staff estimates and calculations.

[1] Commercial bank exposure to ECCU governments is defined as the sum bank holdings of T-bills and other government securities in the ECCU teritorries, percent of total bank assets.

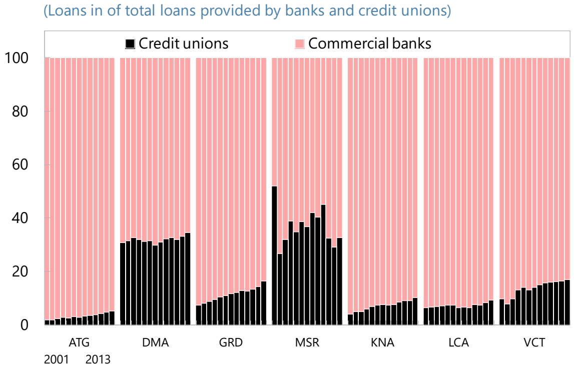
Holdings of NBFI's deposits at the commercial banks have increased steadily over time (Figure 2). Credit unions are the largest NBFI deposit holders in the banking system.[6] In *Dominica*, for instance, credit unions maintain deposits in the banking sector of about 5 percent of GDP.[7] In *St. Vincent and the Grenadines*, about 10 percent of commercial bank deposits belong to NBFI's. Due to this large presence of wholesale institutional deposits, ECCU commercial banks may be more susceptible to abrupt withdrawal of liquidity. And shocks affecting credit unions could potentially spill over to commercial banks, and vice-versa.

Figure 2. Linkages between Credit Unions and Commercial Banks

Credit unions' market share has reached significant levels in Dominica and Montserrat.

Share of Loans by Credit Unions

(Loans in of total loans provided by banks and credit unions)

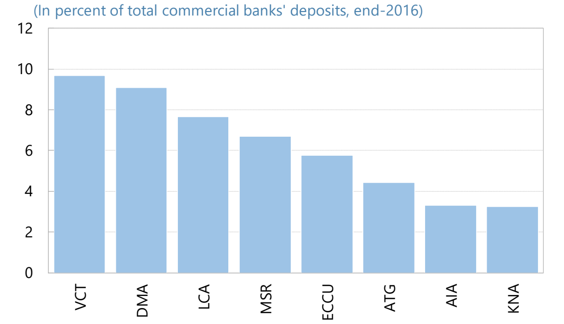


Sources: World Council of Credit Unions; IMF, IFS, and staff calculations.

Meanwhile, growing NBFIs' deposits in commercial banks constitute significant share of bank liabilities in several jurisdictions.

ECCU Banks: Share of NBFI's Deposits

(In percent of total commercial banks' deposits, end-2016)



Source: ECCB; and IMF staff estimates and calculations.

Note: NBFI = non-bank financial institutions, VCT=St. Vincent and the Grenadines, DMA = Dominica, LCA = St. Lucia, MSR=Montserrat, ECCU = Eastern Caribbean Currency Union, ATG = Antigua and Barbuda, AIA = Anguilla, KNA = St. Kitts and Nevis.

[6] Credit unions represent a significant share of lending in some jurisdictions, such as Dominica and Montserrat, where participation rates stand around 100 percent of population. Participation rates above 100 percent may signify more than one credit union account per person. Data for 2016. Source: World Council of Credit Unions.

[7] This is partly because they qualify for the 2 percent minimum saving deposit rate. See Myrvoda and Reynaud (WP/18/70) for discussion of the minimum saving deposit rate.

This paper aims to assess commercial banks' vulnerability to shocks through the interbank network. Given that foreign incorporated banks (branches) do not hold capital independently from their parent, the analysis is based solely on the interbank exposure network of locally incorporated banks, which covers about half of the regional banking sector. However, this is not a major limitation of the analysis, as (i) foreign banks are in general better capitalized and hold to more strict lending requirements as dictated by foreign parent's internal policies, which reduces the risk of bankruptcy affecting the network (asset shock); and (ii) the parent can ultimately provide liquidity support, for example, for brand reputation reasons, thereby reducing the chance of triggering a systemic event if affected by liquidity pressures (liability shock). Given the lack of detailed data on bank-credit union exposures, assessment of this type of risk is not covered in this paper. Bank exposures to other NBFI's and sovereigns are also excluded due to data limitations.

III. METHODOLOGY

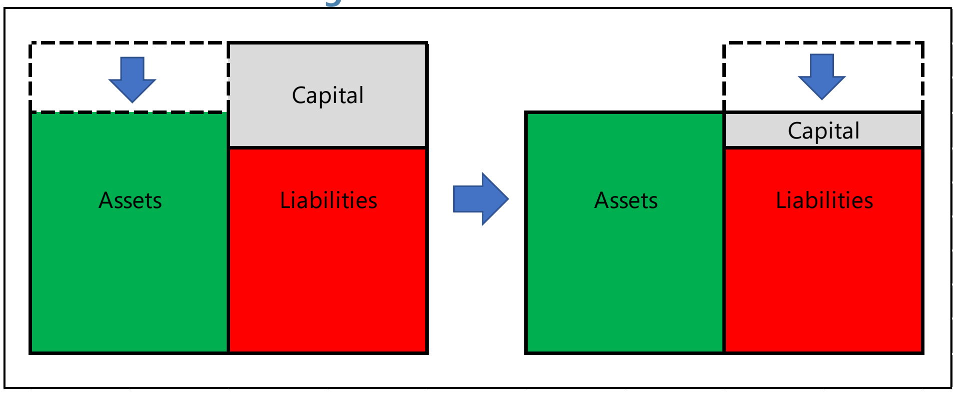
The starting point is the balance sheets of all locally incorporated bank institutions in the ECCU. Interbank exposures are captured by individual banks' bilateral net asset positions. Banks' shock absorption capacity is captured by capital and liquid assets. The results in this paper are based on the balance-sheet network analysis methodology in Espinosa-Vega and Sole (2010). It computes the extent to which the bankruptcy of a bank can inflict capital losses on other banks as it defaults on its liabilities. Depending on the degree of bank interconnectivity and capitalization, this can potentially trigger a cascade of bank failures as the effect ripples through the system, and as the losses from claims on the defaulted banks erode the capital of other banks exposed to it.

In addition, liquidity shocks to banks' balance sheets, for example by way of funding withdrawals, can force banks to fire sale assets if not replaced with other funding sources. This could be important in the context of the ECCU, as the ECCB has limited lender-of-last-resort (LOLR) facilities, and no deposit insurance.[8] If a bank is in need to sell assets under liquidity pressures, it might have no choice but to accept a depressed price, thus reducing its asset and equity value.

The simulations include two types of shocks: a Credit Shock (CS) and a Funding Shock (FS). Under a CS, a bank is assumed to suffer a loss on the asset side of its balance sheet. As claims on other banks are recorded as an asset, when other banks default, the value of the claim declines as it is unlikely that the creditor bank recovers the claim in full value. As a result, the capital of the bank declines. This is illustrated in Figure 3.

[8] As per the ECCB Agreement Act (1983), banks can utilize the ECCB's Lombard facility as a source of emergency liquidity support.

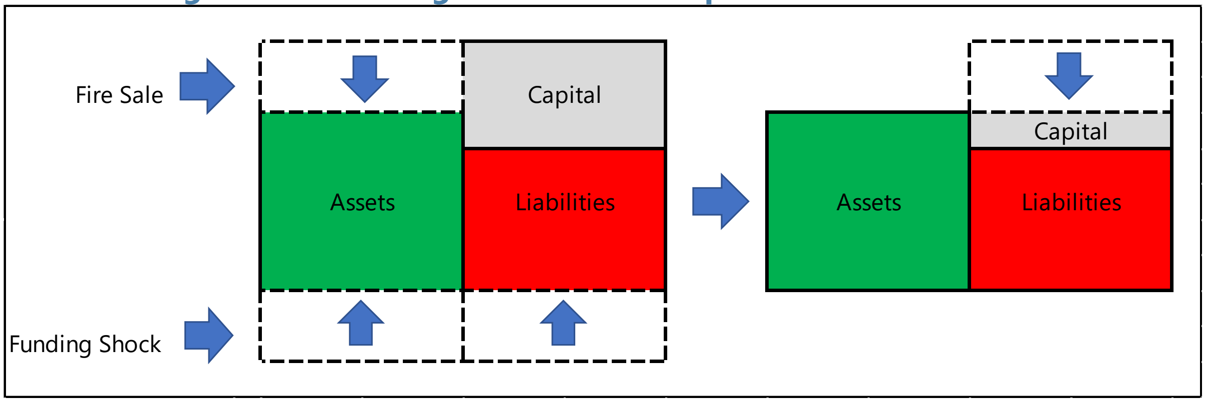
Figure 3: A Credit Shock



In the simulation, if the losses exceed the value of its capital then the bank "defaults". The simulation identifies the extent to which the failure of each and all banks in the network triggers a cascade of defaults of other banks. It starts by setting the default of a bank, and then observing the loss of asset values of other banks that were exposed to it. To this end, other banks' defaulted claims are taken away from their balance sheets. If, as a result, the defaulted banks' capital turns negative, they become insolvent and can trigger loss of asset values and potentially a second round of defaults. This process continues until no further banks default. In the CS, it is assumed that other banks can fully replace any funding they were sourcing with the bankruptcies in the simulation.

In the case of a FS, it is assumed that there is a sudden withdrawal of funding from each and all of the banks in the network, thus a liability shock. The resulting sudden shortfall in funding sources results in a reduction of the affected bank's balance sheet if it cannot find an alternative source of funding to replace it. Under normal market conditions, a bank could sell assets at a price equivalent to its value, thus having no impact on the bank's capital. However, if a bank faces fire sale conditions as it is forced to liquidate assets, this could result in a reduced price and thus a capital loss (Figure 4). This could be the case, for example, when the market is under a liquidity shortage and assets turn illiquid, or if a bank holds large positions in certain assets, thus finding it difficult to find interested or able buyers. In this situation, losses in some banks could turn capital negative and cause a default. In this way, the initial FS can lead to further subsequent FS and CS as other banks default. The simulations thus illustrate how resilient the banking system is to FS.

Figure 4: A Funding Shock under Illiquid Market Conditions



Before proceeding with the stress tests, the capital of each bank is adjusted by deducting the minimum requirement (8 percent risk-weighted assets), and non-performing loans (NPLs) net of provisioning. The first adjustment aligns the analysis with the supervisory perspective (Chan-Lau, 2010). The second adjustment entails deducting NPLs net of provisioning. The initial capital is also adjusted for under-provisioning due to collateral undervaluation. This provides a more conservative starting point in light of the typical difficulties in the region to realize assets at book values, including protracted and costly resolution of collateral[9] (Annex 1). The analysis therefore assumes that a bank "defaults" when the adjusted capital turns negative.

[9] This is in general due to a combination of factor, including debtor-friendly foreclosure laws, lack of specialized courts, absence of prior pledge (lien) registries, and shallow property markets.

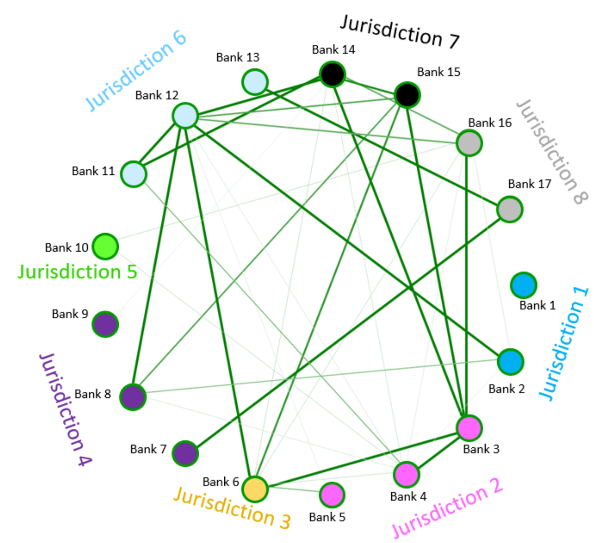
IV. Simulation results

A. Individual Bank shocks

The simulations in this section assume simultaneous credit and funding shocks in each and all banks individually, and then analyze the impact on other regional banks through the network. For the liquidity shock, it is assumed a 50 percent haircut in the fire sale of assets, and a 65 percent roll-over ratio of interbank debt.[10] This is a tail-risk scenario with a low probability of occurrence, particularly given the conservative definition of bank failure due to adjusted capital.

ECCU jurisdictions and banks are identified using a numbering scheme (Figure 5), to avoid the identification of individual banks. Calculations are based on data as of end-June 2017, including 17 locally incorporated banks operating in 8 ECCU jurisdictions.

Figure 5. Interbank Network[1]



[1]Lines display interbank exposures, defined as net credit in percent of lender's capital. Capital defined as total qualifying capital adjusted for under-provisioning, excluding net NPLs and above 8% of risk-weighted assets regulatory minimum.

Results

The results are summarized with two sets of indicators for the identification of the network's vulnerability points. First, each bank's systemic importance is measured by the impact of its failure on other banks. This is captured by a series of summary indicators: number of bank failures; failed capital (average percent of asset loss in other banks); number of contagion rounds; and index of contagion (the percent of capital loss in the system). Second, each individual bank's vulnerability is determined by the extent to which it is exposed to the "failure" of other banks in the network. This is captured by the vulnerability level (number of other failures triggered) and an index of vulnerability (average percent of capital loss of a bank due to the individual failure of all other banks).

Figure 6 illustrates the cascading effects through the network. The "failure" of bank 12 (jurisdiction 6) leads to the "failure" (defined as a negative adjusted capital) of eight other banks within two contagion rounds, nearly half of the ECCU locally incorporated banking system. Similarly, "failure" of bank 14 (jurisdiction 6) leads to "failure" of four other banks, but with smaller, albeit significant, losses to the system of 17 percent. "Failure" of bank 4 (jurisdiction 2) in one contagion round would have led to "failure" of two other banks and

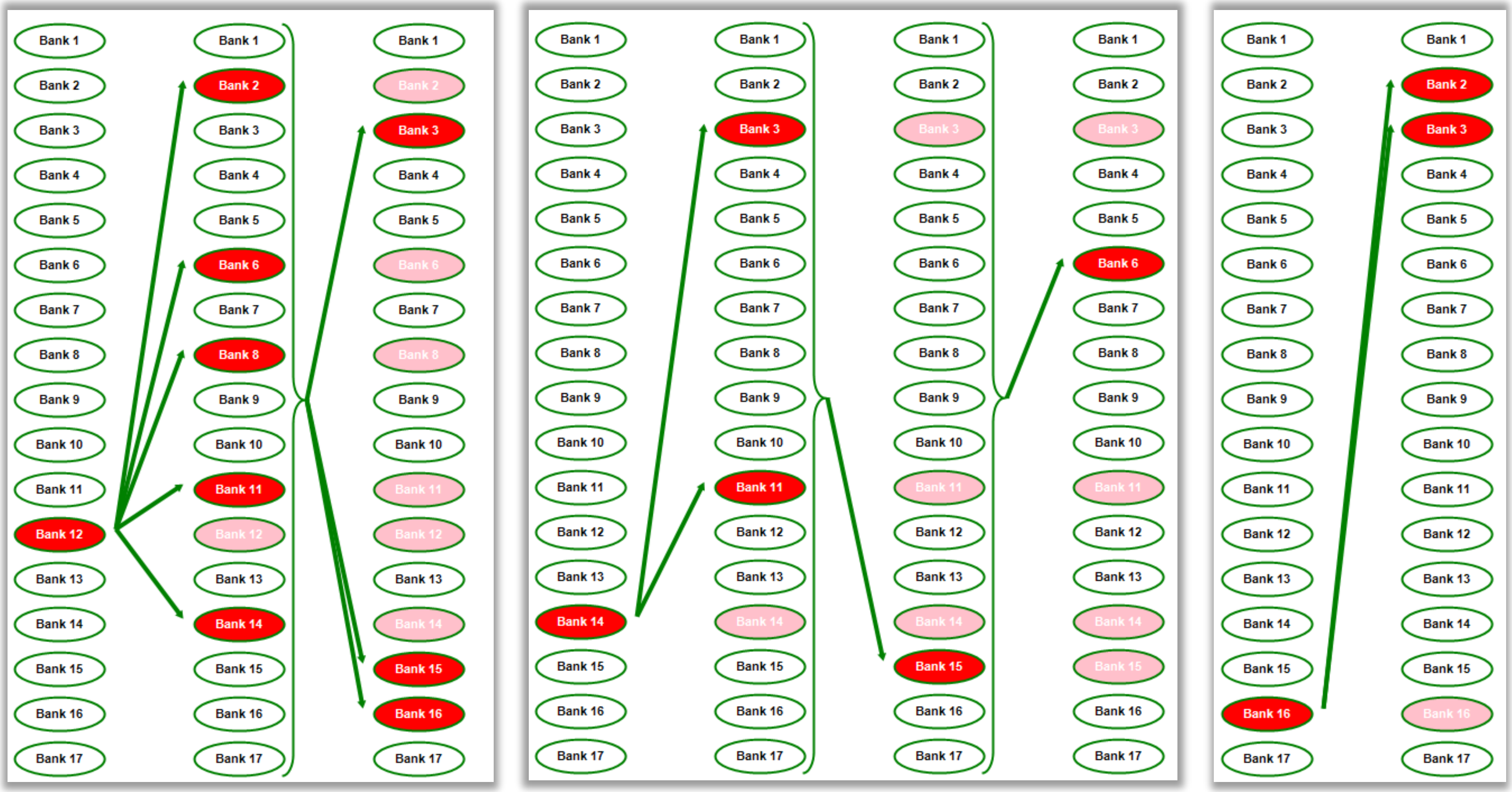
[10] Corresponding to parameter values of δ=1 and ρ=0.35. See Espinosa-Vega and others (2010) for details.

produced losses of 18 percent of the banking system. Other banks are assessed to be less systemically important in this set up, as their “failure” results in relatively smaller, if any, losses to the banking system.

The results highlight the systemic importance of some regional banks, particularly in jurisdiction 6, and to a lesser extent jurisdiction 7 (Figure 7). Bank 12 appears particularly systemic, inducing the “failure” of eight banks and the highest capital loss in the system of nearly 50 percent. Banks 2 and 14 also appear systemic with systemic capital loss (failed capital) of near 30 percent. Banks 12 and 14 also show the highest index of contagion. More than half of the banks induce at least one contagion round, while bank 14 leads to 3 rounds, the highest number in the exercise.

In terms of vulnerability, the simulations indicate that bank 2 (jurisdiction 1) and bank 3 (jurisdiction 2) are the most vulnerable. This is measured by the vulnerability level, where “failure” of six other institutions would lead to “failure” of bank 3; and “failure” of four other institutions would lead to “failure” of bank 2. Banks 6 and 8 also appear vulnerable in terms of capital losses when other banks failed, indicating relatively more substantial net-exposures within the network.

Figure 6. Representation of Systemic Interbank Exposure[1]



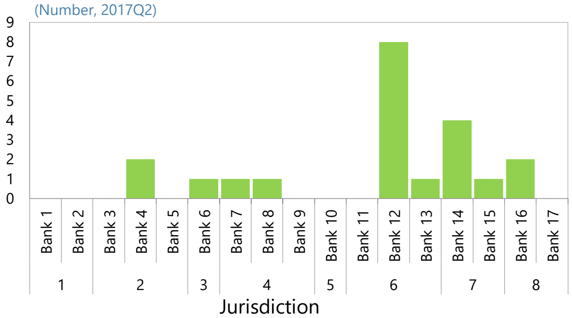
[1] Figure illustrates how a "failure" of banks highlighted in red in the first column propagates through the system. Number of columns indicates contagion rounds (n-1). "Failed" banks are highlighted in red. Cells in pink identify banks "failed" in previous contagion round.

Figure 7. Simulation Results

Simulation results highlight systemic importance of bank 12, whose "failure" would lead to the demise of 8 other banks…

***Number of Induced Failures*[1]**

(Number, 2017Q2)

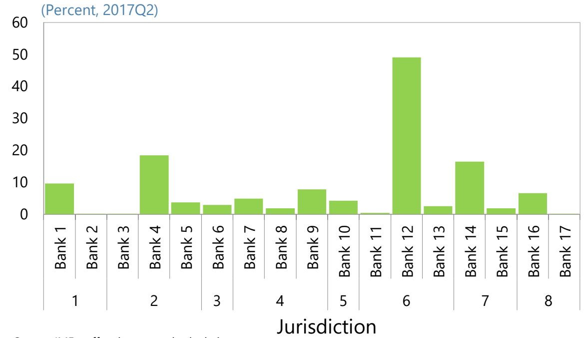


Source: IMF staff estimates and calculations.
Induced failures is defined as the number of bank failures induced by the failure of the bank specified on horizontal axis. Missing bar signifies zero.

… and the loss of nearly half the assets.

Failed Capital[1]

(Percent, 2017Q2)

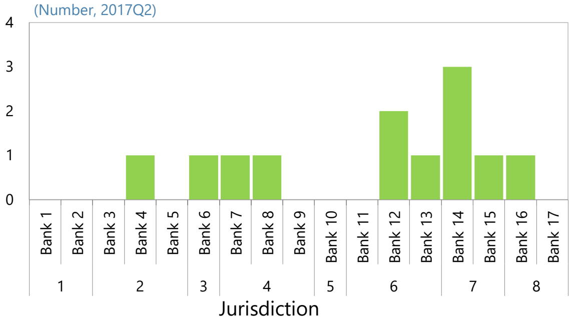


Source: IMF staff estimates and calculations.
Failed capital is defined as the amount of capital lost within the system due to the failure of the bank specified on horizontal axis. Missing bar signifies zero.

"Failure" of bank 14, however, leads to the largest number of contagion rounds.

Contagion Rounds[1]

(Number, 2017Q2)

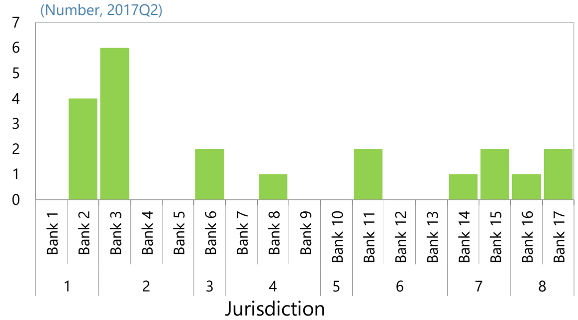


Source: IMF staff estimates and calculations.
Contagion rounds is defined as the number of contagion rounds until no more banks fail due to failure of the bank specified on horizontal axis. Missing bar signifies zero.

Banks 2 and 3 are the most vulnerable in the system, as "failure" of 4 and 6 other banks, respectively, would result in their insolvency.

Vulnerability Level[1]

(Number, 2017Q2)

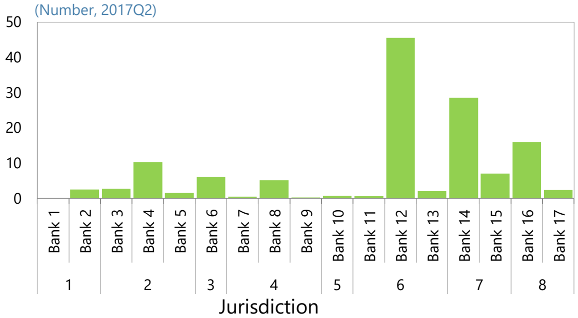


Source: IMF staff estimates and calculations.
Vulnerability level (also hazard) defined as the number of banks whose failure will result in the failure of the bank specified on horizontal axis. Missing bar signifies zero.

Systemic importance of bank 12 is also highlighted by the index of contagion.

Index of Contagion[1]

(Number, 2017Q2)

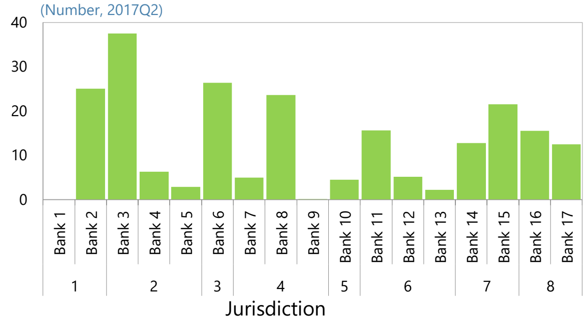


Source: IMF staff estimates and calculations.
Index of contagion defined as average percentage of loss of other banks due to the failure of the bank specified on horizontal axis. Missing bar signifies zero.

And Index of vulnerability highlights banks 3, 2, and 6.

Index of Vulnerability[1]

(Number, 2017Q2)



Source: IMF staff estimates and calculations.
Index of vulnerability averages the percentage of loss of the bank specified on horizontal axis due to the failure of all other banks. Missing bar signifies zero.

[1]Capital defined as total qualifying capital adjusted for overvaluation of collateral, excluding net NPLs, and above 8 percent of risk-weighted assets regulatory minimum.

B. A Macroeconomic Stress-Test Scenario

Significant exposure to potentially large external shocks and natural disasters result in high output volatility in the ECCU. Banks are therefore vulnerable not only to idiosyncratic shocks, but also to economy-wide shocks. This possibility increases the importance of understanding the network links, as it opens the possibility of multiple simultaneous bank failures with rippling systemic consequences. To analyze this risk, this section presents aggregate macroeconomic shocks with customized stress test scenarios. First, we consider scenarios where country-specific macroeconomic shocks are applied individually to each jurisdiction, in the form of a negative GDP shock. This could be representative of a natural disaster, a sudden sharp decline in financing –for example from a sudden stop in citizenship-by-investment flows; or a decrease in access to foreign debt flows under fiscal sustainability concerns. Second, the paper analyzes a tail risk scenario of a negative shock applied to all ECCU members simultaneously. This could capture a regional shock, for example affecting tourism due to international reasons –for example during the September 11, 2001 terrorist attack in the United States which curtailed air travel; or a sharp increase in global interest rates triggering a regional portfolio shift of indigenous banks' liquidity holdings into foreign assets and a credit crunch. These are tail-risk scenarios with low probability of occurrence. In each case, we trace how the shock affects the economy and ultimately propagates in the banks' network through credit and interest rate risk, ultimately affecting banks' capital.[11]

Customized Scenario Assumptions

This section applies a negative tail shock to GDP growth to assess the impact on banks' solvency, and how it propagates throughout the network. The exercise proceeds in two steps. First, it quantifies the impact of the shock on each bank's assets and capital, and assesses which banks would "fail" as a result of the shock. Second, it traces the spillovers from the "failed" banks to other institutions through the interbank bilateral lending matrix. As discussed previously, bank "failure" occurs when capital becomes negative –defined as total qualifying capital adjusted for under-provisioning due to collateral overvaluation, excluding net NPLs above the regulatory requirement minimum of 8 percent of risk-weighted assets.

The impact of the negative tail shock to GDP growth on banks' capital ratios is assessed through two channels. First, impact of the GDP growth shock on NPLs, or the Credit Risk channel. This exercise includes adjustments as per provisioning and collateral valuations. The second channel addresses the impact of the growth shock through an increase in interest rates, consistent with a scenario of a sharp decline in output (see below). The effect on banks' capital of this Interest Rate Risk is analyzed through two effects: the impact on net interest revenues; and the re-pricing of banks' bond holdings. The specific stress test assumptions details are presented in Appendix Table A1.1.

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[11] Foreign exchange risk is excluded from the analysis due to the fixed exchange rate arrangement. The Eastern Caribbean dollar operates under the quasi-currency board arrangement vis-à-vis the U.S. dollar.

Credit risk. The first step is to adjust the initial capital of each bank downward to account for local market frictions affecting credit risk, given the frictions explained above affecting asset valuation in the region. The simulation assumes that the actual value of the collateral is half of the reported value.[12] As mentioned above, this adjustment captures debtor-friendly foreclosure laws and the lack of specialized courts, which make collateral resolution costly and protracted. It also captures the likely decline in collateral values in a negative tail macroeconomic environment assumed in the customized scenario. The adjustment in the collateral values result in higher provisioning requirements, leading to lower bank capital and risk-weighted assets (Appendix 1). A second adjustment is then included to account for under-provisioning. The resulting collateral values are then used to assess the shock impact on bank capital and assets.

After the adjustment of collateral values, the simulation proceeds with the impact of a decline in output growth on NPLs. Shock size is set at two standard deviations below the 2000-16 average of real GDP growth for each country (Figure 8) –and thus the size depends on the historical country-specific growth volatility. A satellite model is calculated to quantify the effect of GDP growth on NPLs, using a panel VAR model estimated for the six independent ECCU economies. The model suggests that a 1 percentage point decline in real GDP growth is associated with about 3 percent increase in NPLs (Beaton et al, 2016). The increase in NPLs is calculated as the product of this elasticity and the country-specific GDP growth shock. Notice that this implies that, in the simulation, the increase in NPLs in each bank is proportional to its initial NPL level –banks with more NPLs would show a higher increase. Relatedly, it is also assumed that provisioning increases.[13] Higher provisioning requirements in turn reduce risk-weighted assets and capital.[14]

Figure 8. Customized Scenario:
Country-Specific Negative Shock to real GDP growth

Country-specific GDP shock: 1/	Percent
Antigua and Barbuda	-10.2
Anguilla	-14.3
Dominica	-4.1
Grenada	-7.0
Montserrat	-3.3
St. Kitts and Nevis	-6.0
St. Lucia	-3.8
St. Vincent and the Grenadines	-3.5

Sources: IMF World Economic Outlook, and staff estimates and calculations.
1/ Assumed GDP shock is calculated as 2000-2016 average of real GDP growth minus two standard deviations (taken over the same period).

Interest rate risk. The simulation assumes that the negative shock to GDP leads to an interest rate spike. The assumed increase in interest rates is informed by the observed increase in interest rates in the Regional Government Securities Market (RGSM). It is calculated as the difference between the maximum bid rate and the actual T-bill yield –defined as the coupon rate on 91-day T-bills issued on the RGSM. This assumption is in line with historical events: exogenous growth shocks – such as natural disasters – are often followed by a spike in T-bills yields – which is

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12 See Appendix 1 for details.

13 A 50% provisioning requirement on new NPLs is assumed.

14 Assuming 100% impact ratio.

capped given a maximum bid rate allowed.[15] For example, following the Tropical Storm Erika, which hit Dominica in August 2015, interest rates on Dominica's 3-month T-bills rose from below 1 percent in June to the maximum rate of 6 percent in September 2015.[16] A similar increase occurred after Dominica was devastated by the Hurricane Maria in September 2017, as the yield on 91-day T-bill paper increased from 2 percent pre- to the maximum rate of 6 percent post-storm.

The increase in interest rates informed by observed RGSM reaction to large shocks is then applied to the net interest margin of each institution. The simulation only considers the direct interest rate risk, defined as the risk incurred by financial institutions when the interest rate sensitivities of their assets and liabilities are mismatched (Čihák, 2007).[17] This direct interest rate risk calculation includes two parts: the flow (net interest income impact) and the stock (repricing impact on bonds):

- ***Net interest income impact.*** It is calculated as the difference between the flow of interest on assets and liabilities. Only assets and liabilities with time to repricing below 12 months are considered, which includes only T-bills and liquid assets due to banks in other ECCB territories.[18] As for the qualifying liabilities, only a conservative measure – 85 percent of total deposits – is included.[19] The product of the resulting asset-liability "gap" and the assumed change in interest rates is the net interest income impact. This results in a decline in net interest income, which reduces banks' capital given the asset-liability maturity gap.

- ***Asset repricing impact.*** Simulations assume that bonds held by banks are "marked-to-market", implying that their market value has a direct impact on bank capital. The impact of the interest rate increase on the market value is proxied using duration of bonds held by banks, which approximates the elasticity of the market value to the rate of return. For simplicity, average ECCU-wide estimated duration of bonds (about 5 years) is applied to all banks. The change in the bond portfolio value is calculated as the product of bank bond holding, bond duration, and the assumed increase in interest rates. Bank capital is then adjusted downward for the negative repricing impact.

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[15] The maximum bid rate is typically specified by the countries' Debt Management Offices in prospectuses before the T-bill issuance.

[16] Value at mid-2017. For countries that do not issue T-bills on RGSM, ECCU average is used. Maximum bid rate is typically set at 6 percent.

[17] The effect of indirect interest rate risk – which results from the impact of interest rate changes on borrowers' ability to service debt – is excluded in this analysis.

[18] Not all qualifying assets and liabilities may have been included in the analysis due to lack to detailed bank-level data.

[19] The share of demand, savings, and foreign currency deposits in total constitutes 85 percent.

Country-Specific Macroeconomic Shocks

After the initial impact of the GDP shock on banks' capital through the credit and interest rate risks, the simulations examine the network cascading effects of a combined credit and funding shock. This includes a default of interbank obligations of undercapitalized banks, and a liquidity shock on banks funded by the "failed" bank, which triggers asset fire sales and further loss of capital as a result. As above, bank "failure" is defined as negative post-shock capital – defined as qualifying capital, adjusted for under-provisioning, net NPLs, and above the regulatory minimum of 8% of RWA. This conservative measure of capital, which considers the broader set of vulnerabilities addressed, provides a useful warning benchmark for the regulators, rather than an outright bank failure.

The results indicate that increased vulnerability and interconnectedness of some banks can have systemic financial instability effects with regional (cross-border) impact (Figure 14).[20] Specifically, results show that banks in jurisdictions 6 and 7 are systemically important for the currency union. The results of the tail GDP growth shock in each jurisdiction yield the following observations:

Jurisdiction 1. The two identified locally incorporated banks in jurisdiction 1 do not appear to have systemic importance through the interbank lending network. A negative shock to GDP in jurisdiction 1 would result in a "failure" of bank 2, but spillovers to other banks are contained. Vulnerability indicators show that "failure" of 4 other regional banks could spill over to bank 2.

Jurisdiction 2. Three locally incorporated banks are domiciled in jurisdiction 2. Simulations show that a negative shock to GDP in jurisdiction 2 would lead to "failure" of bank 3, but also without any further contagion to other banks. Bank 3, however, displays some vulnerability as the "failure" of 6 other banks could spill over.

Jurisdiction 3. The one locally incorporated bank in this jurisdiction would "fail" after a shock to GDP. But the limited interconnectedness with the rest of the region limits its spillovers to other banks. Bank 6 is vulnerable to shocks to other banks, however, given that "failure" of 7 other regional locally incorporate banks could lead to its insolvency.

Jurisdiction 4. Simulations show that, out of the three locally incorporated banks in jurisdiction 4, only one – bank 8 – would fail because of a negative shock to GDP. But no further spillovers occur. This bank is also vulnerable: "failure" of 5 other institutions would lead to its insolvency.

Jurisdiction 5. Only one locally incorporated bank is domiciled in jurisdiction 5. Bank 10's buffers appear sufficiently strong to withstand the shock to GDP designed in this simulation.

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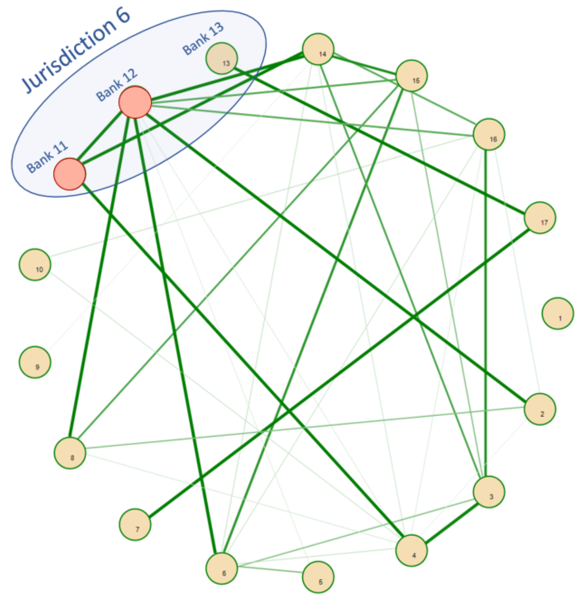
[20] The joint credit and liquidity shock assume a 50 percent haircut in the fire sale of assets and a 65 percent roll-over ratio of interbank debt as in the previous exercise.

Jurisdiction 6. Jurisdiction 6 domiciles three locally incorporated commercial banks. A negative shock to the GDP of jurisdiction 6 would result in a "failure" of two systemically important banks: bank 11 and bank 12, while bank 13 is able to withstand the shock. Figure 9 provides a visual representation of interbank exposure network in this simulation scenario. Figure 14 summarizes the results of individual "failures" of banks 11 and 12. A joint "failure" of banks 11 and 12– only in two contagion rounds – would result in insolvency of 7 other banks from 6 other ECCU jurisdictions (Figure 12, panel a). In this setup, banks 11 and 12 are also assessed to be vulnerable to shocks imposed on other banks. Specifically, an exogenous "failure" of 9 other regional banks would result in the "failure" of banks 11 and 12.

Figure 9. Customized Scenario

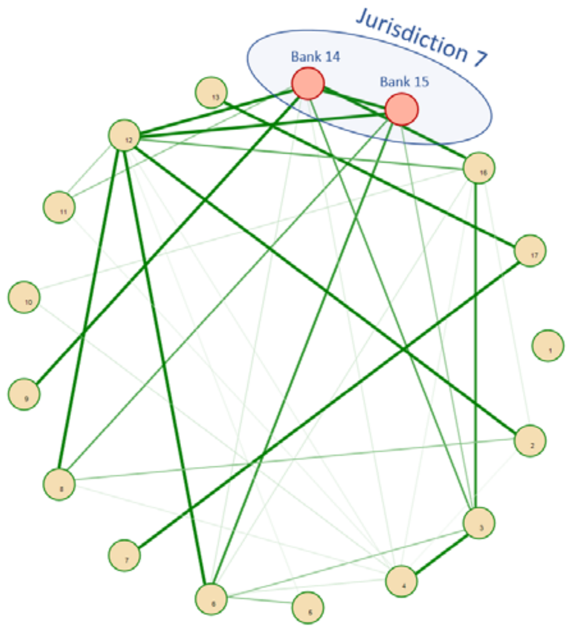
Negative GDP shock to Jurisdiction 6

Interbank Network[1]



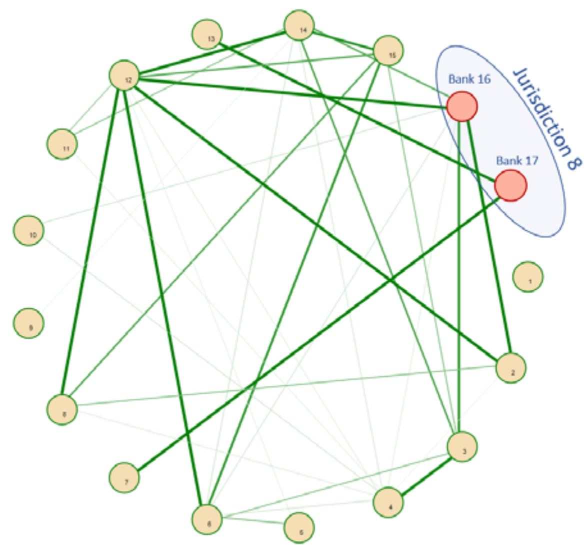
[1]Lines display interbank exposures, defined as net credit in percent of lender's capital. Capital defined as total qualifying capital adjusted for underprovisioning, excluding net NPLs and above 8% of risk-weighted assets regulatory minimum. For jurisdiction 6, post-shock capital used.

Figure 10. Customized Scenario
Negative GDP shock to Jurisdiction 7
Interbank Network[1]



[1]Lines display interbank exposures, defined as net credit in percent of lender's capital. Capital defined as total qualifying capital adjusted for underprovisioning, excluding net NPLs and above 8% of risk-weighted assets regulatory minimum. For jurisdiction 7, post-shock capital used

Figure 11. Customized Scenario
Negative GDP shock to Jurisdiction 8
Interbank Network[1]



[1]Lines display interbank exposures, defined as net credit in percent of lender's capital. Capital defined as total qualifying capital adjusted for underprovisioning, excluding net NPLs and above 8% of risk-weighted assets regulatory minimum. For jurisdiction 8, post-shock capital used.

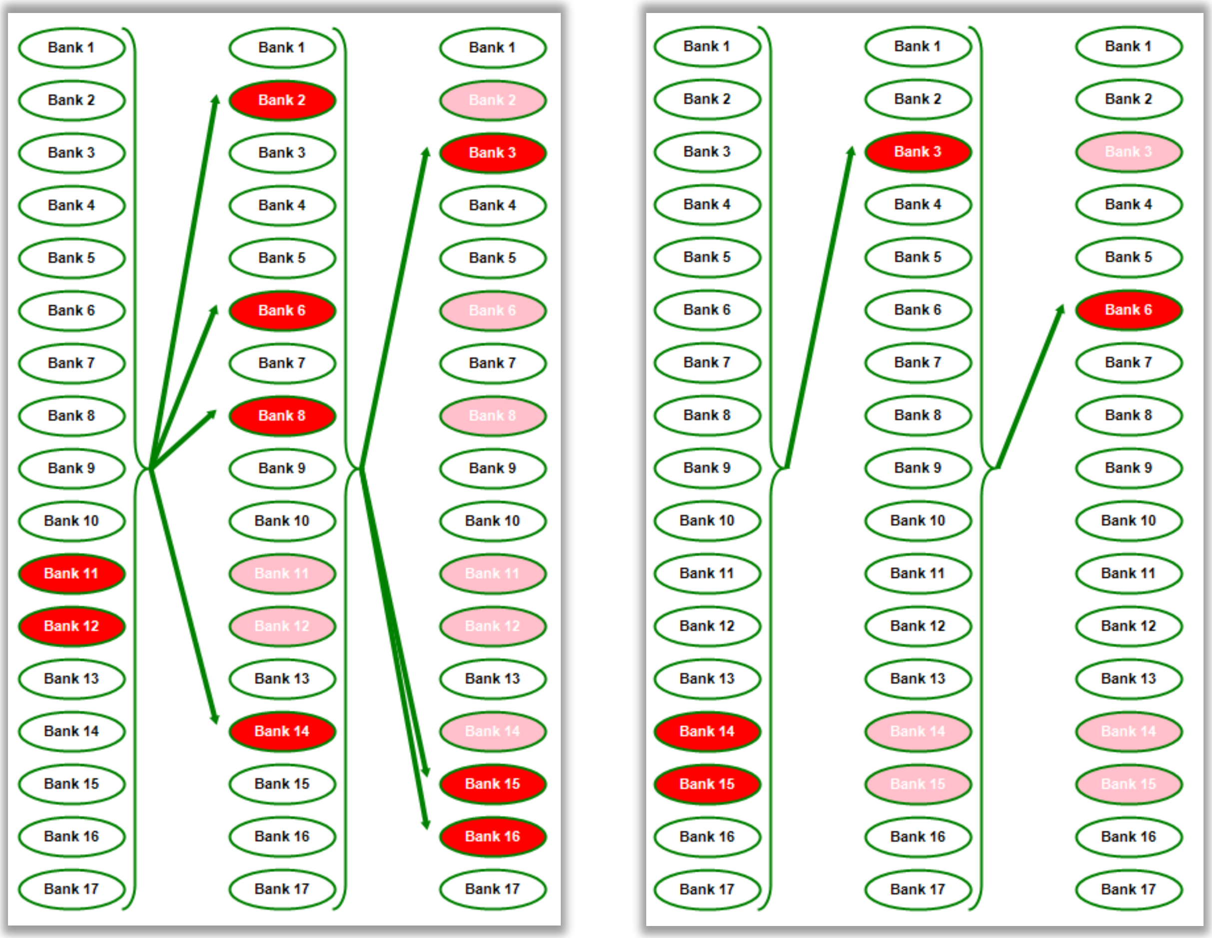
Jurisdiction 7. Banks in jurisdiction 7 also display systemic importance but to a lesser extent than in jurisdiction 6. They also appear relatively vulnerable to other banks' shocks. A negative shock to GDP in jurisdiction 7 would lead to "failure" of both locally incorporated commercial banks: 14 and 15. Visual representation of interbank network in this simulation is presented in Figure 10. Systemic importance of banks 14 and 15 is less pronounced as their "failure" spills over to 2 other institutions in jurisdictions 2 and 3 (Figure 12, panel b). However, the level of vulnerability of banks 14 and 15 remains high, given that "failure" of 9 other institutions would lead to their demise.

Jurisdiction 8. Simulation results indicate that locally incorporated banks in jurisdiction 8 are not systemically important but are vulnerable to other banks (Figure 11). A shock to GDP in jurisdiction 8 would result in the "failure" of both locally incorporated banks: 16 and 17. But only bank 16 would have a knock-on effect on another institution: bank 2 (jurisdiction 1). Bank 16 is also highly vulnerable to other banks' health, given that "failure" of 8 other banks could fail bank 16.

Figure 12. Customized Scenario: Representation of Systemic Interbank Exposures[1]

A. Shock to Jurisdiction 6: "Failure" of banks 11 and 12

B. Shock to Jurisdiction 7: Failure of banks 14 and 15



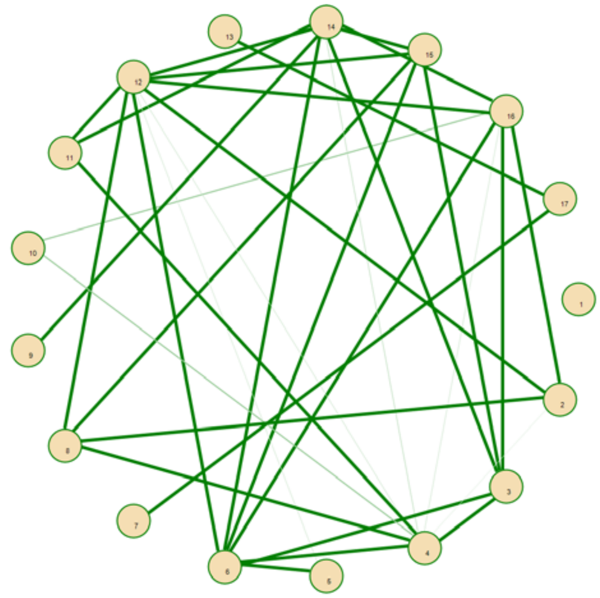
[1]Figure illustrates how a "failure" of banks highlighted in red in the first column propagates through the system. "Failed" banks are highlighted in red. Cells in pink identify banks "failed" in previous contagion round.

ECCU-Wide Shock

This section analyzes an exogenous shock that affects the entire ECCU region. It is assumed that all countries experience 2-standard deviations real GDP growth shocks below their corresponding historical averages. Visual representation of interbank network – defined as net credit in percent of adjusted lender's capital – is presented in Figure 13.

This tail risk scenario is designed to highlight the vulnerabilities of the ECCU economies to extreme external shocks with low probability of occurrence. Possible channels include through tourism, a key industry in all ECCU countries that depends on global conditions, or the effect of tail shocks to global financial stability that could cause spillovers in the ECCU given the large size of the financial sector and the participation of foreign banks in the region.

Figure 13. Customized Scenario
Negative GDP shocks to All Jurisdictions
Interbank Network[1]



[1]Lines display interbank exposures, defined as net credit in percent of lender's capital. Capital defined as total qualifying capital adjusted for under-provisioning, excluding net NPLs and above 8% of risk-weighted assets regulatory minimum. For all jurisdictions, post-shock capital is used.

A region-wide shock leads to "failure" of 10 of the 17 locally incorporated banks in the ECCU (Figure 14, banks highlighted in red in column "ECCU"). The remaining 7 banks, however, would continue their operations with positive capital. In part, this result reflects better capitalization and limited interconnectedness with other regional locally incorporated banks.

Figure 14. Customized Scenario: Main Indicators Under Narrow Definition of Capital
(Capital defined as total qualifying capital above regulatory minimum and excluding net NPLs[1])

Legend: Jurisdiction/region to which negative GDP growth shock is applied to

"Failed" banks, defined as having negative post-shock capital (post-shock K - 8%*RWA - Net NPLs)[1] Capital adjusted for market frictions.

Induced Failures

		Jurisdiction 1	2	3	4	5	6	7	8	ECCU
Jurisdiction 1	Bank 1	0	.	.	.	.	.	.	.	0
	Bank 2	0	.	.	.	.	.	.	.	8
Jurisdiction 2	Bank 3	.	0	.	.	.	.	.	.	8
	Bank 4	.	0	.	.	.	.	.	.	0
	Bank 5	.	0	.	.	.	.	.	.	0
Jurisdiction 3	Bank 6	.	.	0	.	.	.	.	.	8
Jurisdiction 4	Bank 7	.	.	.	0	.	.	.	.	0
	Bank 8	.	.	.	1	.	.	.	.	8
	Bank 9	.	.	.	0	.	.	.	.	0
Jurisdiction 5	Bank 10	.	.	.	.	0	.	.	.	0
Jurisdiction 6	Bank 11	.	.	.	.	.	8	.	.	8
	Bank 12	.	.	.	.	.	8	.	.	8
	Bank 13	.	.	.	.	.	0	.	.	0
Jurisdication 7	Bank 14	.	.	.	.	.	.	3	.	8
	Bank 15	.	.	.	.	.	.	3	.	8
Jurisdiction 8	Bank 16	.	.	.	.	.	.	.	1	8
	Bank 17	.	.	.	.	.	.	.	0	0

Contagion Rounds

		Jurisdiction 1	2	3	4	5	6	7	8	ECCU
Jurisdiction 1	Bank 1	0	.	.	.	.	.	.	.	0
	Bank 2	0	.	.	.	.	.	.	.	2
Jurisdiction 2	Bank 3	.	0	.	.	.	.	.	.	2
	Bank 4	.	0	.	.	.	.	.	.	0
	Bank 5	.	0	.	.	.	.	.	.	0
Jurisdiction 3	Bank 6	.	.	0	.	.	.	.	.	2
Jurisdiction 4	Bank 7	.	.	.	0	.	.	.	.	0
	Bank 8	.	.	.	1	.	.	.	.	2
	Bank 9	.	.	.	0	.	.	.	.	0
Jurisdiction 5	Bank 10	.	.	.	.	0	.	.	.	0
Jurisdiction 6	Bank 11	.	.	.	.	.	3	.	.	2
	Bank 12	.	.	.	.	.	2	.	.	2
	Bank 13	.	.	.	.	.	0	.	.	0
Jurisdication 7	Bank 14	.	.	.	.	.	.	3	.	2
	Bank 15	.	.	.	.	.	.	3	.	2
Jurisdiction 8	Bank 16	.	.	.	.	.	.	.	1	2
	Bank 17	.	.	.	.	.	.	.	0	0

Hazard

		Jurisdiction 1	2	3	4	5	6	7	8	ECCU
Jurisdiction 1	Bank 1	0	.	.	.	.	.	.	.	0
	Bank 2	4	.	.	.	.	.	.	.	12
Jurisdiction 2	Bank 3	.	6	.	.	.	.	.	.	12
	Bank 4	.	0	.	.	.	.	.	.	0
	Bank 5	.	0	.	.	.	.	.	.	0
Jurisdiction 3	Bank 6	.	.	7	.	.	.	.	.	12
Jurisdiction 4	Bank 7	.	.	.	0	.	.	.	.	0
	Bank 8	.	.	.	5	.	.	.	.	12
	Bank 9	.	.	.	0	.	.	.	.	0
Jurisdiction 5	Bank 10	.	.	.	.	0	.	.	.	0
Jurisdiction 6	Bank 11	.	.	.	.	.	9	.	.	12
	Bank 12	.	.	.	.	.	9	.	.	12
	Bank 13	.	.	.	.	.	0	.	.	0
Jurisdication 7	Bank 14	.	.	.	.	.	.	9	.	12
	Bank 15	.	.	.	.	.	.	9	.	12
Jurisdiction 8	Bank 16	.	.	.	.	.	.	.	8	12
	Bank 17	.	.	.	.	.	.	.	2	2

Index of Contagion

		Jurisdiction 1	2	3	4	5	6	7	8	ECCU
Jurisdiction 1	Bank 1	0	.	.	.	.	.	.	.	0
	Bank 2	2	.	.	.	.	.	.	.	29
Jurisdiction 2	Bank 3	.	3	.	.	.	.	.	.	29
	Bank 4	.	0	.	.	.	.	.	.	0
	Bank 5	.	0	.	.	.	.	.	.	0
Jurisdiction 3	Bank 6	.	.	4	.	.	.	.	.	29
Jurisdiction 4	Bank 7	.	.	.	0	.	.	.	.	0
	Bank 8	.	.	.	5	.	.	.	.	29
	Bank 9	.	.	.	0	.	.	.	.	0
Jurisdiction 5	Bank 10	.	.	.	.	0	.	.	.	0
Jurisdiction 6	Bank 11	.	.	.	.	.	46	.	.	29
	Bank 12	.	.	.	.	.	46	.	.	29
	Bank 13	.	.	.	.	.	0	.	.	0
Jurisdication 7	Bank 14	.	.	.	.	.	.	27	.	29
	Bank 15	.	.	.	.	.	.	27	.	29
Jurisdiction 8	Bank 16	.	.	.	.	.	.	.	14	29
	Bank 17	.	.	.	.	.	.	.	2	7

Souce: Authors' calculations.

[1] Capital defined as post-shock total qualifying capital above 8 percent of risk-weighted assets regulatory minimum minus NPLs net of provisioning. Total qualifying capital corrected for underprovisioning due to market frictions. Induced failures is defined as the number of bank failures induced by the failure of the specified bank. Contagion rounds is defined as the number of contagion rounds until no more banks fail due to failure of the specified bank. Vulnerability level (also hazard) defined as the number of banks whose failure will result in the failure of the specified bank. Index of contagion defined as average percentage of loss of other banks due to the failure of the bank specified.

V. CONCLUSIONS

This paper presents stress tests to the ECCU banking network, designed as severe but plausible shocks with low probability of occurrence. Two types of shocks are applied based on the network analysis framework in Espinoza-Vega and Sole (2010): combined asset and liability shocks to each individual bank (individual-bank shock), and a tail growth shock to each country (country shock) and to the entire region (regional shock). The growth shock includes the balance sheet impact through credit and interest rate risk channels. The exercises control for possible weaknesses that are specific to the ECCU region which affect bank capitalization, including asset valuations and the high levels of NPLs. The tests are also designed as a warning instrument for the regulator by focusing on capital shortfalls below the 8 percent minimum capital requirement.

- *Individual-bank shock.* This is representative of the "failure" of an individual institution and the resulting spillover to other regional banks. The results identify two potentially systemic banks that could induce "failure" of 8 and 4 other banks with capital losses in the system of nearly 50 and 30 percent, respectively. The simulation also identifies two most vulnerable banks, where "failure" of six and four other banks would result in undercapitalization of these institutions.

- *Country shock.* Country-wide tail macroeconomic shock scenarios are relevant in the region in light of the small country size, which limits the scope for productive diversification –and thus banks' portfolios diversification opportunities. Countries are also often affected by large shocks that affect the entire economy, especially natural disasters. The simulations assume an output growth decline of two standard deviations relative to the historical average. The results indicate potentially significant capital shortages in other jurisdictions through the regional network when the shock is applied to two out of eight ECCU jurisdictions. In one such jurisdiction, half of the remaining banks in the network turn out undercapitalized. Growth shocks to a second jurisdiction also results in four "failures". Other jurisdictions seem to result in more contained network contagion, although a few "fail" at least one another institution, in light of relatively weaker links and/or sufficient capital buffers, despite the large originating shock.

- *Regional shock.* A region-wide macroeconomic tail shock of the same magnitude as above, applied to all ECCU countries simultaneously, results in undercapitalization of over half of the banks in the network. This low high intensity and probability shock tests the system resilience to extreme global events that could affect all ECCU countries. Examples include a shock affecting the tourism industry; sudden portfolio shift of the relatively large financial sectors prominent in the region; sudden stop in financing flows from unstable CBI flows; or global shocks affecting governments' financing access given prevalent high levels of public debt.

Simulation results highlight remaining vulnerabilities of the ECCU locally incorporated banking system. Relative to their capital, interbank exposures of the locally incorporated institutions have declined in recent years. This is primarily attributed to increased capital accumulation, higher provisioning for non-performing loans and lower NPLs.

Further research is needed to expand the network with the inclusion of non-bank financial institutions, which in some ECCU countries are also of systemic importance given their size, and net asset connections with banks. The most prominent example is the credit union sectors, which in general are characterized by relatively weaker regulation requirements and regulator’s insufficient enforcement powers and limited capacity and resources.

VI. APPENDICES

A. Appendix 1. Adjusting Bank Capital for Collateral Overvaluation[21]

Several market frictions in the ECCU make collateral resolution costly and often protracted. These include shallow property markets, debtor-friendly foreclosure laws, lack of specialized courts, and absence of prior (lien) registries in the ECCU, among others. To reflect these frictions in the simulation, we assume that the actual collateral is worth about half of the reported value. Correction for the overvalued collateral results in higher provisioning requirements. This leads to lower bank capital. Calculations are first done separately for substandard, doubtful, and loss loans, given varying provisioning guidelines for each category (Prudential Credit Guidelines of the ECCB, 1997), and then summed up.[22] [23]. Adjustments to capital is performed in steps:

1. A*ctual collateral value of NPLs* = NPLs * required collateral-to-total loan ratio (124 percent). The latter is taken as the average estimate for the Caribbean from the World Bank Enterprise Survey (2016), and includes reported estimates for Antigua and Barbuda, The Bahamas, Barbados, Dominica, St. Kitts and Nevis, St. Lucia, and Trinidad and Tobago.

2. *Collateral after the haircut* = actual collateral value * (1- haircut). Calculations assume a haircut of about 52 percent.[24]

3. $Provisioning\ needed = \sum_{i=1}^{3}(NPL - collateral\ after\ haircut) * prov_i$, where *i*-loan category (substandard, doubtful, and loss), $prov_i$ = required level of provisioning (in percent) for each loan category.

4. *Underprovisioning* = actual provisioning made – provisioning needed for collateral with haircut

[21] At end-2017, the ECCB issued new *Valuation Prudential Standards for Licensed Institutions under the Banking Act* to strengthen valuation procedures in the ECCU, with the intended date of implementation by mid-2018.

[22] According to the ECCB provisioning guidelines (1997), required level of provisioning on pass, and special mention loans is 0%, substandard (other than loans and advances to government or fully secured by government or government securities or by cash) is 10%, doubtful – 50%, and loss – 100%.

[23] New prudential guidelines on impaired assets are currently under consideration by the ECCB.

[24] Calculations assume a haircut of 52 percent, and NPV of bank collection on NPL collateral of 48 percent. Specifically, assuming loan = 100, loan repayment before default = 50, collateral value = 124, discount rate = 6.5%, and time till collateral sale = 7 years, NPV of bank collection on collateral = ((124-(100-50))/(1.065)^7) = 0.48. Collateral needed in percent of loan value is the average for the Caribbean taken from the World Bank Enterprise Survey (2016). A conservative 6.5 percent value of discount rate is assumed (weighted average lending rate was 8.5, and prime lending rate = 5 percent at end-2017).

5. *Bank capital after adjustment for underprovisioning* = initial capital – underprovisioning * impact ratio, where the impact ratio on capital is assumed to be 100%.

6. *Risk-weighted assets (RWA) after adjustment for underprovisioning* = initial RWA – initial RWA * impact ratio (100%).

The new calculated indicators for capital and RWA are used to assess the impact of negative shock to GDP on bank capitalization.

Appendix Table A1.1: Customized Scenario Assumptions

Scenario Shock:	
Country-specific GDP shock: 1/	
Antigua and Barbuda	-10.2
Anguilla	-14.3
Dominica	-4.1
Grenada	-7.0
Montserrat	-3.3
St. Kitts and Nevis	-6.0
St. Lucia	-3.8
St. Vincent and the Grenadines	-3.5
1. Credit risk	
a. Underprovisioning due to collateral overvaluation	
Assumed collateral, % loan	124% 2/
NPL collateral book value	= NPLs* assumed collateral, % loan
Haircut on collateral	52% 3/
Required provisioning on NPLs: 4/	
Performinig loans	
Pass	0%
Special mention	0%
Non-performing loans	
Substandard	10% 5/
Doubtful	50%
Loss	100%
b. NPL increase due to negative GDP shock	
Assumed increase in NPLs 6/	
Antigua and Barbuda	31%
Anguilla	43%
Dominica	12%
Grenada	21%
Montserrat	10%
St. Kitts and Nevis	18%
St. Lucia	11%
St. Vincent and the Grenadines	11%
Assumed provisioning of additional NPLs	50%
2. Interest rate risk	
a. Net interest income impact	
Assets with time to repricing <12 months: T-bill holding	
Liabilities with time to repricing <12:	
share of deposits 7/	85%
Assumed change in interest rate due to GDP shock (pptss): 8/	
Antigua and Barbuda	3.4
Anguilla	3.4
Dominica	4.1
Grenada	2.5
Montserrat	3.4
St. Kitts and Nevis	3.4
St. Lucia	3.0
St. Vincent and the Grenadines	4.0
b. Bond repricing impact	
Assumed average duration of bonds held 9/	5.0

Sources: Authors' estimates and calculations.

1/ Assumed GDP shock is calculated as 2000-2016 average of real GDP growth minus two standard deviations (taken over the same period).

2/Required collateral in percent of loan as reported in World Bank Enterprise Survey. Average taken for Antigua, Barbados, The Bahamas, Dominica, St. Kitts and Nevis, St. Lucia, and Trinidad and Tobago.

3/ Large haircut reflects the difficulty to foreclose collateral (Cihak, 2007).

4/ Source: ECCB Prudential Credit Guidelines, 1997.

5/ Note that the regulation requires 0% provisioning on substandard loans and advances to Government or fully secured by Government or Government securities or by Cash. Other substandard loans require 10% provisioning.

6/ Calculated as the product of country-specific GDP shock multiplied by the elasticity of NPL growth with respect to GDP growth (-3). See IMF WP/16/229 for details.

7/ At end-2017Q2, 85% deposits constituted saving, demand, and foreign currency deposits in total deposits of ECCU commercial banks (excludes time deposits and EC$ cheques and drafts).

8/ Country-specific increase in interest rates calculated as the difference between the maximum rate and the actual latest coupon rate of RGSM 91-day bill issued by the country. ECCU average taken for countries that do not issue 91 bills on RGSM. WHile the maximum rate varies by country, 6% rate is assumed for all jurisdictions for simplicity.

9/ Average duration of bonds issued on RGSM in 2016. Duration approximates the elasticity of the market value of assets to the rate of return (for details see Cihak, 2007).

B. Appendix 2. Bank Network Analysis: Time Dimension

Changes in balance sheet strength and bilateral exposures indicate that network analysis should be updated regularly to reassess vulnerabilities and monitor progress. To that effect, this appendix replicates some of the tests in the paper using end-of-year data during 2014-2017.

This appendix presents the evolution of the interbank exposures of the ECCU locally incorporated banks over the last 4 years to assess the stability of the results. To analyze interconnectedness of the ECCU banks over time, simulations are repeated using data for end-2014, 2015, 2016, and mid-2017. Results across different periods are reported in Appendix Figure A2.

In this appendix, capital is defined as total qualifying capital above the regulatory minimum of 8 percent of risk-weighted assets, and excluding NPLs net of provisioning. Results presented in this appendix are based on the adjusted definition of capital that is *not* corrected for under-provisioning due to overvaluation of collateral to account for market frictions. Data limitations impede such adjustment of capital for every period considered in this analysis.

For comparability, the sample of banks is restricted to institutions operational during the entire period of 2014-2017. Banks that were acquired or merged with another institution, or those created during this period were removed from the sample. This explains the total of 15 banks presented in Appendix Figure A2 and the omitted banks.

Simulations highlight significant reduction in banks' vulnerability over time. This trend is largely explained by capital accumulation, as the number of undercapitalized banks declined significantly after 2015. In large part, this is attributed to the regulatory intervention of the ECCB between 2015 and 2017, which resulted in mergers/acquisitions of insolvent banks in Antigua and Barbuda and Anguilla. It is also party due to the overall improvement of banks' capital positions in response to higher capital requirements of the new Banking Act (2015). Lower NPLs and higher provisioning rates also helped lower banks' vulnerability. Better economic outlook post-GFC also helped improve banks' vulnerabilities to some extent.

Simulation results point to lower contagion across the ECCU locally incorporated banks over time. Improved bank capital positions strengthened banks' ability to withstand shocks and cushion the impact. This trend is reflected by the declining number of induced 'failures' for all banks and the lower index of contagion for most banks over time.

Simulation results emphasize the systemic importance of bank 12. The number of induced 'failures' and the number of contagion rounds has declined over time for bank 12. But, as of mid-2017, it continued to remain highly contagious financial institution, able to cause undercapitalization of 7 other regional banks, and leading to losses of nearly half of the system in this simulation.

The results of this dynamic assessment of bank interconnectedness highlight the importance of capital buffers to absorb shocks. The ECCU has achieved significant progress in strengthening bank capital buffers and lowering sensitivity to shocks. Given the region’s susceptibility to external shocks, and structural deficiencies –including difficulties associated with property valuation, costly and time-consuming foreclosure procedures, among others – this calls for continued efforts to improve vulnerabilities of the ECCU banking sector.

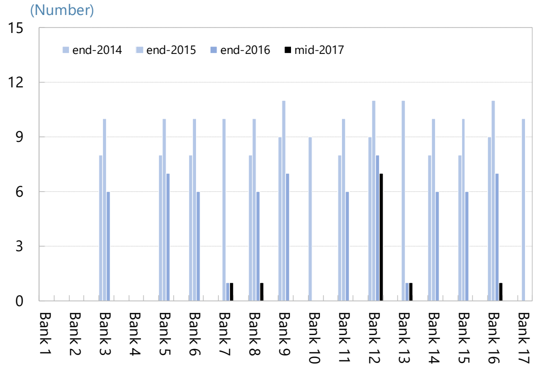
Appendix Figure A2. Simulation Results

Assumed shock: Individual Bank Failure

Capital defined as total qualifying capital, above 8 percent regulatory minimum, excluding net NPLs.

Simulation results highlight declining interconnectedness within the ECCU locally incorporated banks. Bank 12 remains highly systemic for the region in this definition of capital.

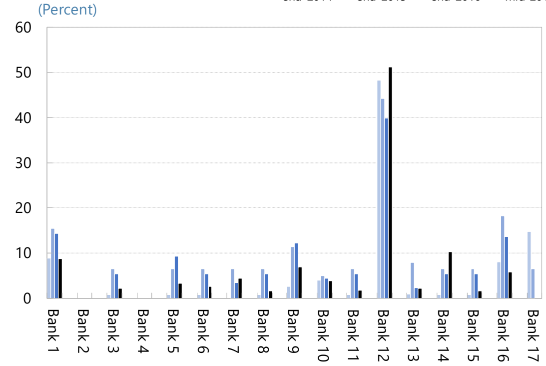
Number of Induced Failures
(Number)



Source: IMF staff estimates and calculations.

Latest data suggest that 'failure' of bank 12 would lead to undercapitalization of 7 other regional banks, amounting to nearly half of the sector.

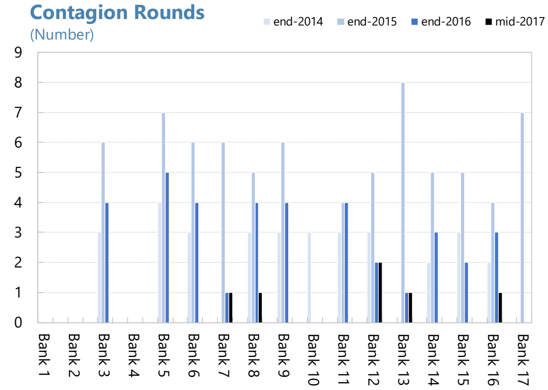
Failed Capital
(Percent)



Source: IMF staff estimates and calculations.

The number of contagion rounds has declined over time…

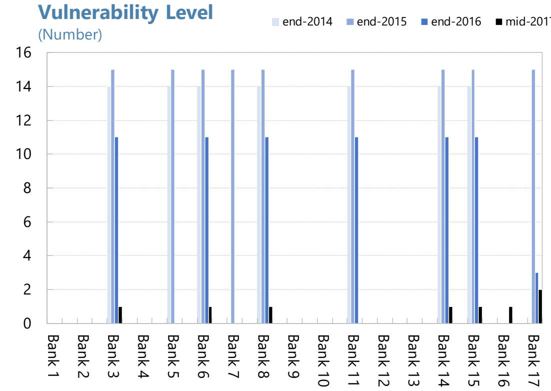
Contagion Rounds
(Number)



Source: IMF staff estimates and calculations.

…along with the vulnerability.

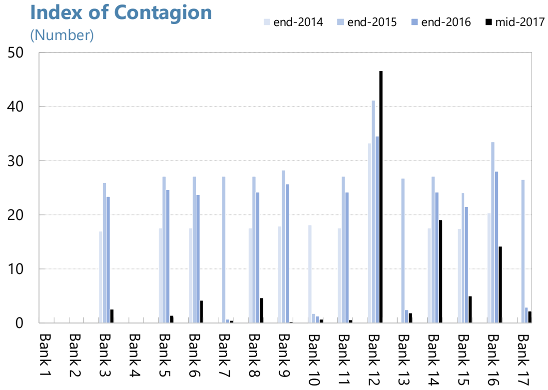
Vulnerability Level
(Number)



Source: IMF staff estimates and calculations.

Systemic importance of bank 12 is also highlighted by the index of contagion.

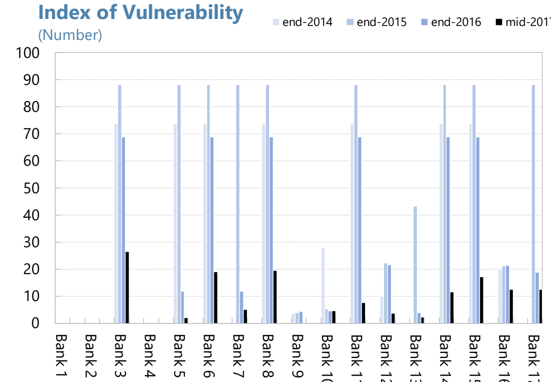
Index of Contagion
(Number)



Source: IMF staff estimates and calculations.

And Index of vulnerability highlights banks 3, 6, and 8.

Index of Vulnerability
(Number)



Source: IMF staff estimates and calculations.

[1]Capital defined as total qualifying capital adjusted for overvaluation of collateral, excluding net NPLs, and above 8 percent of risk-weighted assets regulatory minimum.

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