Currency networks in cross-border bank lending[1]

Stefan Avdjiev[2] and Előd Takáts[3]

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We investigate currency networks in cross-border bank lending using a new dataset. We start by mapping the major currency networks in global banking. While the dollar tends to dominate at the global level, the euro has a strong role in lending to and from the euro area and emerging Europe. Next, we present evidence that these currency networks exert a significant influence on cross-border bank lending. During the taper tantrum, dollar lending behaved very differently from lending in other currencies – it was associated with safe haven flows to the United States, virtually unchanged flow dynamics vis-à-vis other advanced economies, and strong withdrawals from emerging markets. Furthermore, we show that this pattern was shaped by interbank lending, while dollar shares did not affect lending to non-banks.

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[2] Bank for International Settlements; e-mail: stefan.avdjiev@bis.org

[3] Bank for International Settlements; e-mail: elod.takats@bis.org

1. Introduction

Cross-border bank lending totals almost $30 trillion, or around 40% of global GDP. Understandably, researchers have examined this channel for international capital flows from a number of angles. One perspective that has received relatively less attention, not least due to data limitations, is the currency denomination of cross-border bank lending. Yet, this perspective is becoming more relevant as monetary conditions diverge between the United States, on the one hand, and the euro area and Japan, on the other.

The immediate concern is to understand how the monetary policy divergence could affect cross-border bank lending. However, there is a broader set of economic questions worthy of investigation: What role do currencies play in international bank lending? Does currency composition affect the behaviour of cross-border bank lending? For instance, does dollar lending from the same lending banking system to the same borrowing country behave differently than euro lending? If so, how?

Answering the above questions in a robust manner was not possible in the past due to data constraints. More specifically, previously available datasets failed to simultaneously provide the three necessary dimensions needed to properly identify currency networks in cross-border bank lending: (1) the currency composition of the claims, (2) the location, or residence, of the borrower and (3) the nationality of the lending bank. This has changed recently: the newly available Stage 1 enhancements of the BIS International Banking Statistics (IBS) simultaneously provide data on all three dimensions, thus making it possible to engage in an empirical examination of currency networks in the context of cross-border bank lending.

In this paper, we utilise this newly available dataset to (i) map currency networks in cross-border bank lending, and to (ii) examine the degree to which these currency networks matter for the behaviour of cross-border bank lending. Our mapping identifies two large currency networks: the dollar network accounts for around one-half of all outstanding claims, while the euro network for around one-third. Furthermore, our mapping also reveals that the euro network is very much concentrated in the euro area and emerging Europe. The other currency networks, among which the largest is that of the Japanese yen, are much smaller than the two dominant ones. Our mapping also shows that the borrowing country is a more important determinant of currency choice than the originating banking system.[4]

Our analysis suggests that these currency networks matter. In particular, we investigate the taper tantrum period as an example of a shock which affected one network, the dollar network, differently than other currency networks. We find that exposure to the US dollar lending mattered, but not uniformly. While overall higher exposure to US dollar lending was associated with stronger lending this overall picture masks substantial heterogeneity. After controlling for other potential drivers of cross-border bank lending, we find evidence of safe haven flows to the United States, largely unaffected flow dynamics to other advanced economies, and flight from emerging markets. Furthermore, our analysis also reveals that this pattern was largely shaped by interbank lending. By contrast, non-bank lending was not affected by currency denomination in a statistically significant manner. Finally, the impact of

[4] For instance, while US banks tend to lend in dollars and European banks in euros, even US banks tend to lend in euros to emerging Europe and even European banks tend to lend in dollars to emerging Asia.

currency denomination is economically significant: our decomposition analysis suggests that the US dollar share accounted for nearly half of the explained variation in cross-border lending dynamics across lender-borrower pairs.

The findings suggest that currency networks matter for financial vulnerabilities. This adds to our growing understanding of financial stability risks posed by cross-border bank lending. The financial crisis and the euro area crisis have taught us that the origin of cross-border bank lending matters: stressed lending banks tend to lend less with potential negative consequences for domestic credit (see for instance Takáts (2010) and Avdjiev et al (2012) for a formal analysis). Our study suggests that *in addition* to identifying lending banking systems the currency composition might also matter - particularly for interbank lending. For instance, dollar denominated lending from the United Kingdom to emerging market banks suffered as the US prepared to tighten its policies during the taper tantrum. By extension, though this had to be confirmed by further studies, euro lending to emerging markets from non-euro countries might be affected by the European Central Bank's monetary policy. Hence, policy makers in emerging economies might also want to monitor the currency composition of cross-border bank lending to their countries.

The rest of the paper is organised as follows. The second section discusses the relevant literature. The third section introduces the data. The fourth maps currency networks and provides some descriptive statistics. The fifth section formally analyses currency networks during the 2013 taper tantrum episode. The sixth section concludes.

2. Related literature

The paper fills a gap at the intersection of three strands of international finance literature: (1) the literature on the determinants of cross-border bank lending, (2) the literature on domestic versus foreign currency bank lending and (3) the triple coincidence literature in international finance.

First, our work is naturally related to the literature on cross-border bank lending. In fact, it can be seen as a natural extension towards incorporating the newly-available currency network dimension in it. There exists a rich literature on cross-border bank lending at a global level (eg De Haas and Van Lelyveld (2011), Rose and Wieladek (2011), Cetorelli and Goldberg (2012), Giannetti and Laeven (2012), De Haas and Van Horen (2012), Buch et al. (2014), Cerutti et al (2014), Cerutti et al (2015)). In addition, a number of papers have investigated lending to emerging markets more specifically (eg McGuire and Tarashev (2008), Takáts (2010), Cetorelli and Goldberg (2011), Schnabl (2012), Avdjiev et al (2012), Beck (2014)). Avdjiev and Takáts (2014) comes closest to our approach by using the Stage 1 enhancements and explicitly considering borrowing country and lending banking system related drivers of cross-border bank lending. Yet, this paper extends the analysis in three dimensions: (i) broadens the scope of the analysis from emerging market borrowers to the global economy, (ii) maps currency networks explicitly and (iii) fully exploits the currency composition dimension in the analysis.

Second, the explicit focus on currency denomination in our work is also linked to the small but growing literature analysing foreign currency lending or financial dollarization. The main contribution of our work is that we extend this line of research from the traditional domestic lending focus to cross-border bank lending.

Furthermore, we perform a global study and do not narrow the analysis to regions where domestic FX lending is particularly relevant, such as Latin America or emerging Europe (see for instance in Nagy, Jeffrey and Zettelmeyer (2011)). Finally, similarly to some of this FX lending literature, we also consider determinants of lending related to the borrowing country[5] and to lending banking system.[6]

Third, our approach also related to the nascent literature on the absence of a triple coincidence in international finance (Shin (2012)). More concretely, we explicitly build on and provide empirical support for the insight that national income boundaries, decision making units and currency usage realms do not necessarily overlap in the modern global financial system. In particular, we focus on two specific dimensions of the above idea. First, when mapping currency networks, we investigate how a given currency - and the monetary policy associated with it - might affect economic conditions far beyond the borders of the issuer country that issues it. For example, US monetary policy affects US dollar liquidity not only in the United States, but also globally. And in doing so, it affects the availability of funding around the world (see Bruno and Shin (2015a and 2015b)).

The second aspect of the triple coincidence framework that we examine is related to the distinction between decision making units and national income boundaries. Namely, when investigating cross-border bank lending we focus on the lender nationality, which is a proxy for the relevant decision making unit, and not on the residence of the lender. In other words, we follow the insight of the triple coincidence literature by shifting focus from national boundaries to economically relevant decision-making units. In order to see the importance of this shift, consider the following example. Let's assume that a German bank lends to its subsidiary in the United Kingdom which uses these funds to lend further to the United States. What matters for this cross-border lending is the general health of the German bank. As we have banking system data, the health of the German bank is better captured by health indicators of the German banking system than those of the UK banking system. Our approach allows us to identify this lending as a loan from the German banking system to the United States (a link that would not appear in any residence based statistic) and disregard the loan from Germany to the UK and the loan from the UK to the US (the only links that would appear in a residence based statistic).

[5] The literature has uncovered many borrowing country factors as drivers of foreign currency lending: the lack of macroeconomic policy credibility, inflation volatility, low institutional quality, interest rate differentials, financial market development, and foreign funding of bank credit (e.g., Barajas and Méndez Morales (2003), De Nicolo, Honohan and Ize (2003), Rajan and Tokatlidis (2005), Rosenberg and Tirpák (2009), Basso, Calvo-Gonzalez and Jurgilas (2011)).

[6] Some newer research, such as Krogstrup and Tille (2015) comes even closer to our work by analysing lending credit conditions in the home market of the lending currency.

2. Data

Stage 1 data

To study the behaviour currency networks in cross-border bank lending we need data which contain the following three dimensions: (A) the currency composition of cross-border claims; (B) the residence of the borrower and (C) the nationality of the lending banking system

The need for the currency composition of lending (A) is the most obvious of the three. The availability of this dimension is the most important pre-condition for the mapping of currency lending networks. Furthermore, it is also necessary to investigate the impact of currency networks on bank lending flows by controlling for the impact of currency fluctuations on changes in the outstanding stocks of cross-border bank claims.[7] For instance, a move in the euro-dollar exchange rate mechanically leads to changes in the US dollar value of euro-denominated claims. Thus, the changes in BIS IBS claims, which are expressed in US dollars, also reflect currency movements. The adjustment for currency movements is particularly relevant, because the events that we might want to investigate in the context of currency networks, such as the US taper tantrum, tend to coincide with large exchange rate movements.[8]

Besides the currency composition of cross-border bank lending, we also need to correctly identify both borrowers and lenders to map cross-border lending stocks and flows. To identify borrowers, we need information on their residence (B). To identify lenders, we need to identify the nationality (ie the home of the highest level banking entity in the corporate chain) of the lending bank (C), which in turn is used as a proxy for the decision making unit for the supply of cross-border bank lending.[9]

There are two main reasons why one needs to identify the nationality and not the residence of the lending banking system. The first arises because of financial centres. Returning to the example from the previous section, suppose that a bank headquartered in Germany extends loans to it subsidiary in the United Kingdom – which lends it further to a borrower in the United States. To make the example as straightforward as possible, assume that all lending is in dollars. To study the dollar network, one needs to establish the link between the US borrower and the German bank – and disregard the intermediated loan from the German bank to the subsidiary in the UK and also the link between the UK subsidiary and the US borrower. To

[7] In addition to exchange rate fluctuations, the quarterly flows in the locational datasets are corrected for breaks in the reporting population.

[8] In fact, correcting for exchange rate changes is also crucial for our analysis. When demonstrate that the consolidated data, which is not adjusted for currency fluctuations, instead of the Stage 1 data, which is adjusted for currency fluctuations, would have generated results that are drastically different from the ones we obtain in our benchmark estimation. Please see the Sensitivity analysis section for further details.

[9] Strictly speaking, the nationality of the lending bank identifies the country of ownership, and not necessarily the decision making unit. In general, ownership and decision making is likely to be the closer in banking systems which are more centralised (eg German and French banks) – and the they might not so strongly overlap in banking systems which are more decentralised (eg Spanish banks). However, in the case of cross-border bank lending the overlap between ownership and decision making is likely to be stronger than in the case of local lending – which makes nationality a reasonable, though not perfect, proxy for decision making in this our case. See CGFS (2010) for further discussion of models of international banking.

achieve this, we need the nationality of the banking system. A dataset which lack that dimension, ie a dataset with information only on the residence of the lender, would only be able to identify the German-UK and UK-US link (exactly those links that we would want to disregard) and fail to identify the link that we are interested in, the link between the German bank and the US borrower. This example also highlights why traditional residence based balance of payment data provides misleading picture on such links (Shin (2012)).

The second reason is "same country" lending, ie cross-border bank lending which originates from a banking system and is being lent back to the same country where the bank is headquartered. These links are often substantial: for instance, foreign subsidiaries of US banks held approximately $700 billion worth of claims on US residents. Once again, data on the nationality of the lending banking system is essential to identify these volumes: data based on the residence of lenders by definition could not show such links.

The recently implemented Stage 1 Enhancements to the BIS international banking statistics (IBS) provides the necessary three dimensions:[10]

A. the currency composition of cross-border claims,

B. the residence of the borrower and

C. the nationality of the lending banking system.

The Stage 1 enhanced data are the first consistent dataset to provide all three dimensions at the same time (Table 1). Previously, the BIS IBS data had information on only two of the above three dimensions. The consolidated dataset had information on the nationality of the lending banks (dimension A) and on the residence of the borrower (dimension B), but did not contain a currency breakdown (dimension C). By contrast, the locational data by residence did have information on the currency composition of banks' cross-border claims (dimension C) and on the residence of the borrower (dimension B), but lacked information on the nationality of the lending bank (dimension A). Finally, the locational data by nationality contained dimensions A and C, but not dimension B.

Data availability in the BIS International Banking Statistics

By data dimension

Table 1

	Currency composition (A)	Residence of borrower (B)	Nationality of lending bank (C)
Consolidated Data[1]	No	Yes	Yes
Locational Data[2]			
by Residence	Yes	Yes	No
by Nationality	Yes	No	Yes
Stage 1 data	**Yes**	**Yes**	**Yes**

[1] The BIS consolidated banking statistics groups claims according to the nationality of banks (ie according to the location of banks' headquarters), netting out inter-office positions. [2] The BIS locational banking statistics defines creditors and debtors according to their residence, consistently with national accounts and balance of payments principles.

Finally, even though the new Stage 1 data is not yet fully complete, it is nevertheless representative. On aggregate, information on the nationality of lending

[10] For a detailed description of the enhanced BIS data see Avdjiev et al (2015).

banks is available for more than 90% of global cross-border claims. This ratio varies considerably and tends to be higher for larger counterparty countries.

Lending banking systems and borrowing countries

In selecting the sample for our analysis, we aim to include all internationally significant lending national banking systems and borrowing countries, for which the quality and availability of the new Stage 1 data exceeds a certain threshold. In particular, on the lending side, we include the 27 national banking systems, whose home countries report both, Consolidated data and Stage 1 enhanced locational data (with a breakdown by counterparty country). Those 27 bank nationalities accounted for 93% of all outstanding cross-border claims in the BIS locational data at end-Q4 2014. On the borrowing side, we include 50 recipient countries whose (individual) cross-border bank borrowing exceeded $10 billion at end-2014 and for which the nationality of the lending bank could be identified for at least 80% of all outstanding cross-border claims as of end-2014.[11]

Cross-border bank claims at end-Q4 2014 Table 2

	Lender nationality		
	Advanced economies	Emerging markets	Offshore centres
Borrower location			
Advanced economies	19,264	395	64
Emerging markets	2,285	351	117
Offshore centres	3,454	205	75

[1] In billions of US dollars.

Source: BIS international banking statistics.

At end-2014, the outstanding stock of BIS IBS cross-border bank claims totalled $28.5 trillion. Using the new dimensions in the Stage 1 data, we can simultaneously identify the nationality of the lending bank and the location of the borrower for 92% ($26.2 trillion) of the global total. Nearly three quarters ($19.3 trillion) of the bilaterally-identified claims represented lending by banks from advanced economies (AEs) to borrowers in AEs (Table 2). The second largest component of global cross-border bank lending was the one from AE banks to offshore centres – it stood at $3.5 trillion (or 13% of the global aggregate). "AE-to-EME" lending (ie lending by AE banks to EME borrowers) was also substantial – it amounted to $2.3 trillion (or 9% of global cross-border lending). Meanwhile, cross-border lending by EME banks, which has been growing rapidly over the past few years, stood at $1.1 trillion or around 4% of global cross-border claims. It was fairly evenly distributed among borrowers from AEs ($395 billion), EMEs ($351 billion) and offshore centres ($205 billion).

[11] The 27 lending banking systems are Austria; Australia; Belgium; Brazil; Canada; Switzerland; Germany; Denmark; Spain; Finland; France; Greece; Ireland; India; Italy; Japan; Korea; Luxembourg; Mexico; the Netherlands; Norway; Portugal; Sweden; Turkey; Chinese Taipei; United Kingdom; United States; and the 50 borrowing countries are Angola; Austria; Australia; Belgium; Bulgaria; Brazil; Canada; Switzerland; Chile; China; Cyprus; Czech Republic; Germany; Denmark; Spain; Finland; France; Greece; Croatia; Hungary; Ireland; Israel; Italy; Japan; Korea; Liberia; Lithuania; Luxembourg; Morocco; Marshall Island; Malta; Mexico; Nigeria; the Netherlands; Norway; New Zealand; Poland; Portugal; Romania; Russia; Sweden; Slovenia; Slovakia; Turkey; Chinese Taipei; Ukraine; United Kingdom; United States; Vietnam; South Africa.

3. Currency networks

More than three-quarters of global cross-border claims were accounted for by lending in two major currencies: the US dollar and the euro. Claims denominated in US dollars alone equalled $13.0 trillion, or 45% of the global total. Meanwhile, cross-border lending denominated in euros stood at $9.0 trillion, or 31% of the global aggregate. The third largest currency denomination, the Japanese yen accounts for only around 5% of the global total.

At the aggregate level, the above currency shares are remarkably stable across counterparty sectors (Table 3). The US dollar shares of global cross-border lending to banks (46%) and non-banks (45%) are virtually the same. The same is true for the respective euro shares, with both at 31%. In the case of yen, the difference is more pronounced: cross-border lending to non-banks (6.4%) is almost twice as high as interbank lending (3.6%).

Currency composition of cross border bank lending at end-Q4 2014 Table 3

	Amounts outstanding				Percentage shares		
	All currencies	US dollar	Euro	Japanese yen	US dollar	Euro	Japanese yen
Counterparty sector							
All sectors	28,568	12,940	8,978	1,349	45.3	31.4	4.7
Banks, total	16,180	7,428	5,055	579	45.9	31.2	3.6
Non-banks, total	11,973	5,428	3,660	766	45.3	30.6	6.4
Counterparty countries							
Advanced economies	20,000	8,092	7,876	788	40.5	39.4	3.9
Euro area	7,888	1,310	5,710	181	16.6	72.4	2.3
Of which: intra – EA	4,275	320	3,816	12	7.5	89.3	0.3
United States	4,641	4,078	269	64	87.9	5.8	1.4
Other advanced	7,471	2,704	1,898	543	36.2	25.4	7.3
Offshore centres	3,910	2,476	292	442	63.3	7.5	11.3
Emerging markets	3,434	1,615	383	40	47.0	11.2	1.2
Emerging Europe	578	178	231	5	30.8	40.0	0.9
Latin America	550	401	19	7	72.9	3.4	1.3
Africa and Middle East	434	263	66	5	60.6	15.1	1.2
Emerging Asia	1,872	773	68	22	41.3	3.6	1.2

[1] in billions of US dollars.

Source: BIS international banking statistics.

The variation in the currency composition of cross-border lending across locations is considerably larger (Table 3). In terms of lending to advanced economies, the US dollar and euro shares are roughly equal at 41% and 39%, respectively. Approximately half of US dollar-denominated bank lending to advanced economies is accounted for by cross-border claims on residents of the United States ($4.1 trillion). Similarly, the majority ($5.7 trillion) of euro-denominated cross-border bank lending is directed towards borrowers in the euro area - and most ($3.8 trillion) of that amount represents intra-euro area cross-border claims. Outside the United States and the euro area, the US dollar and the euro still dominate lending to

advanced economies, albeit with somewhat smaller shares (36% and 25%, respectively).

Lending to EMEs tends to be primarily denominated in US dollars as well. The proportion of cross-border claims on EMEs denominated in US dollars (47%) is more than four times higher than that of the euro (11%). Nevertheless, the aggregate EME numbers mask considerable variations across regions. The US dollar accounts for the majority of the claims on Latin America and on Africa and the Middle East (73% and 61%, respectively). Yet, it accounts for less than half (41%) of the lending to emerging Asia and less than a third (30%) of the lending to emerging Europe. In fact, emerging Europe is the only EME region where the euro is the leading currency with around 41% of all claims. The share of yen is negligible at around 1% of lending to all four EME regions.

The dominance of the US dollar is most pronounced in cross-border claims on offshore centres with a share of nearly two thirds (63%) of the total. Conversely, the respective share for the Japanese yen is merely 11%. The share of the euro is even smaller at 8%.

Furthermore, the above regional aggregates conceal even greater heterogeneity at the individual country level across both lending banking systems and individual borrowing countries. For example, the share of lending denominated in US dollars tends to be very high for banks headquartered in EMEs. By contrast, it is fairly low for euro area banks, particularly those from smaller countries, which tend to lend primarily in euros. Banks from larger advanced economies (eg US, UK, Germany France, Japan) tend to have cross-border lending portfolios which are much more balanced across major currencies, albeit exhibiting a slight bias towards their home currency.

In order to explore the above heterogeneity, we create global "heat maps" of bilateral cross-border lending shares for the three most used currencies: the US dollar (Graph 1), the euro (Graph 2) and the Japanese yen (Graph 3). We use the new stage 1 data breakdown for every lender-borrower pair to capture the share of cross-border lending that is denominated in each of these major global currencies. The heat maps reveal several patterns.

Most of the bilateral lender-borrower nodes in our global cross-border bank lending heat map tend to fall in the US dollar network (Graph 1). With a couple of major exceptions (discussed below), most of the AE-to-AE lending tends to be heavily US dollar-denominated. Furthermore, the US dollar accounts for the majority of lending by AE economy banks to three out of the four major EME regions. Finally, EME-to-EME lending also tends be heavily US dollar denominated.

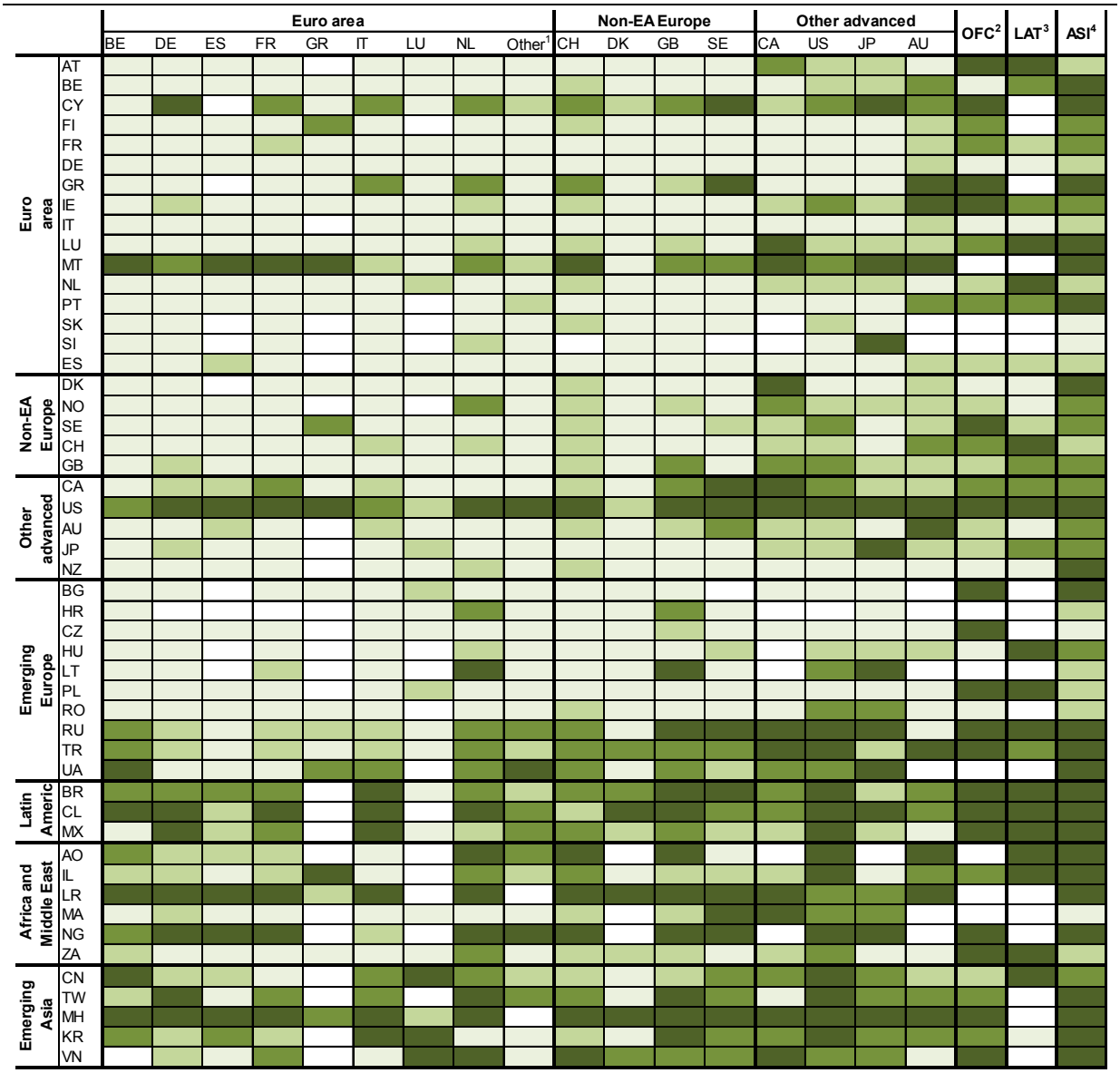
Even though the majority of global cross-border bank lending flows tend to be denominated in US dollars, there is a clearly defined euro network comprising the euro area and emerging Europe (Graph 2). A substantial proportion of the claims either originating from European banks or directed towards European borrowers (both in the euro area and in emerging Europe) is denominated in euros.

The yen network is not as large as its dollar and euro counterparts (Graph 3). It mainly comprises lending to Japanese borrowers – and in some cases lending by Japanese banks. There are only a few yen-heavy pairs in which neither the lender nor the borrower is from Japan.

US dollar share in cross-border bank lending in Q4 2014

By nationality of lending bank (columns) and residence of borrower (rows), in per cent

Graph 1



ASI = Emerging Asia; LAT = Latin America; OFC = Offshore centres.

AO = Angola; AT = Austria; AU = Australia; BE = Belgium; BG = Bulgaria; BR = Brazil; CA = Canada; CH = Switzerland; CL = Chile; CN = China; CY = Cyprus; CZ = Czech Republic; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; FR = France; GB = United Kingdom; GR = Greece; HR = Croatia; HU = Hungary; IE = Ireland; IL = Israel; IT = Italy; JP = Japan; KR = Korea; LR = Liberia; LT = Lithuania; LU = Luxembourg; MA = Morocco; MH = Marshall Island; MT = Malta; MX = Mexico; NG = Nigeria; NL = the Netherlands; NO = Norway; NZ = New Zealand; PL = Poland; PT = Portugal; RO = Romania; RU = Russia; SE = Sweden; SI = Slovenia; SK = Slovakia; TR = Turkey; TW = Chinese Taipei; UA = Ukraine; US = United States; VN = Vietnam; ZA = South Africa.

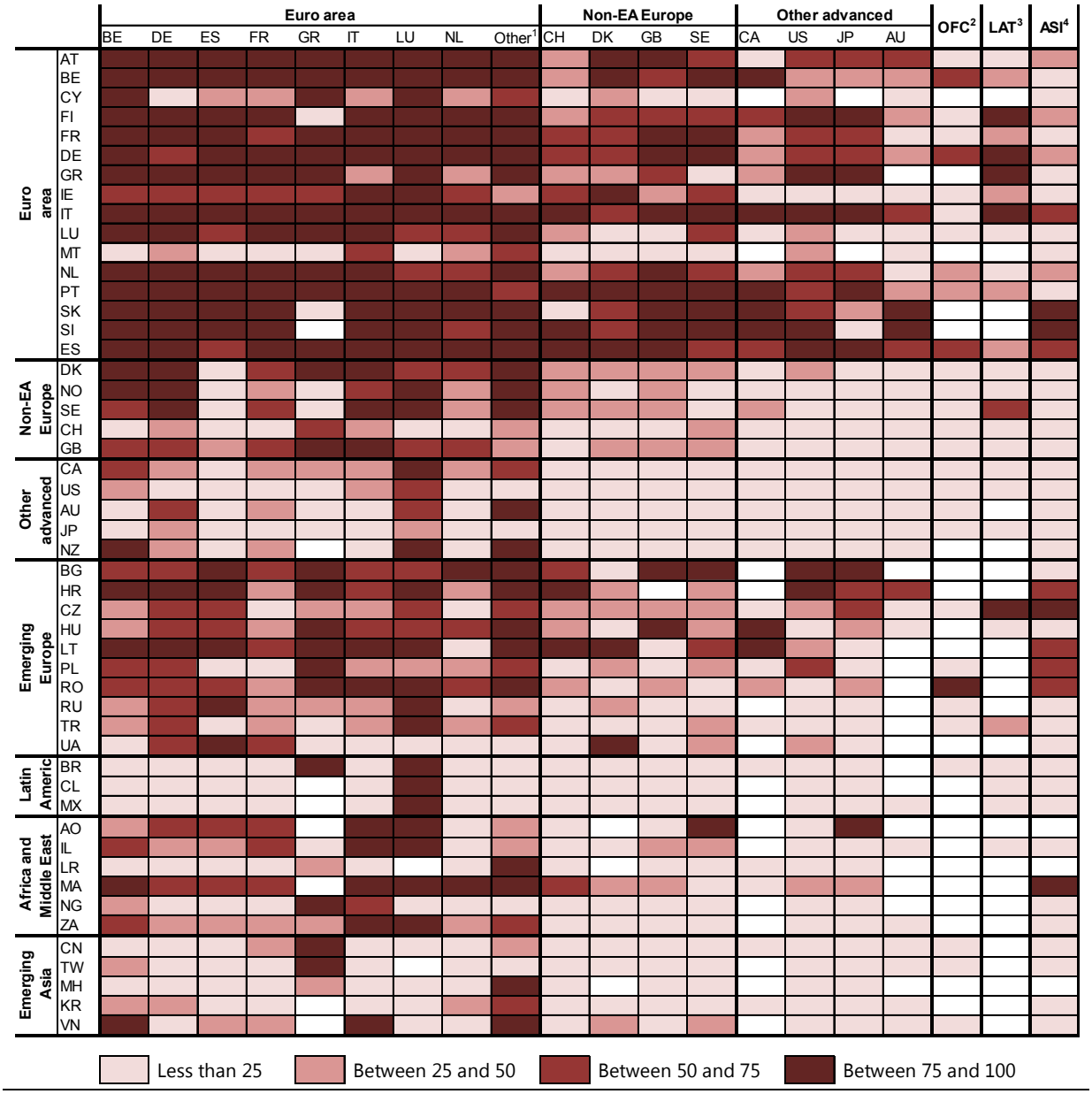
[1] Austria, Finland, Ireland and Portugal. [2] Hong Kong, Singapore and Panama. [3] Brazil, Chile and Mexico. [4] Chinese Taipei, India and Korea.

Source: BIS Stage 1 locational banking statistics by nationality.

Euro share in cross-border bank lending in Q4 2014

By nationality of lending bank (columns) and residence of borrower (rows), in per cent

Graph 2



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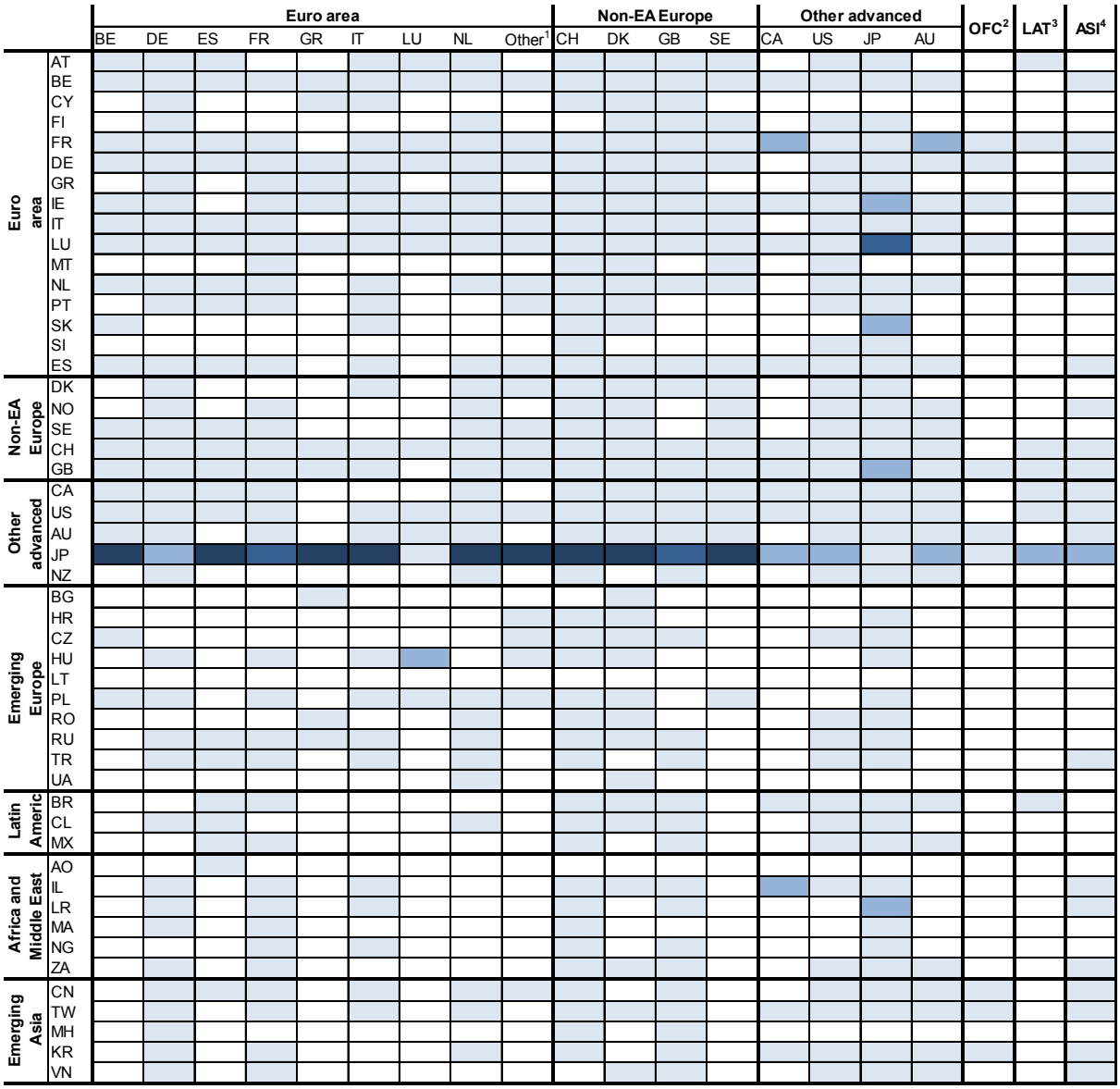
[1] Austria, Finland, Ireland and Portugal. [2] Hong Kong, Singapore and Panama. [3] Brazil, Chile and Mexico. [4] Chinese Taipei, India and Korea.

Source: BIS Stage 1 locational banking statistics by nationality.

Japanese yen share in cross-border bank lending in Q4 2014

By nationality of lending bank (columns) and residence of borrower (rows), in per cent Graph 3



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[1] Austria, Finland, Ireland and Portugal. [2] Hong Kong, Singapore and Panama. [3] Brazil, Chile and Mexico. [4] Chinese Taipei, India and Korea.

Source: BIS Stage 1 locational banking statistics by nationality.

Furthermore, the heat maps suggest that borrowing countries are more relevant for determining the currency of lending than lending banking systems (ie that the shares are more consistent across borrowing countries than across lending banking systems). This visual impression is supported by regression analysis: regressing the US dollar share on borrowing country fixed effects explains around four times more variation than regressing on lending banking system fixed effects. Formal variance decomposition confirms this: the variation in the US dollar share of cross-border lending across lending banking systems is roughly 40% higher than that across borrowing countries.

While very informative about the currency composition of the major bilateral cross-border bank lending relationships across the globe, the "heat maps" in Graphs 1-3 should be interpreted with the caveat that they do not reveal any information about the size the network nodes. For example, since they are solely focused on currency shares, they treat a lender-borrower pair with a USD share of 90% and a total size of $500 billion in an identical way to a pair with the same USD share, but a size of only $1 billion. In order to address this issue and provide a more nuanced perspective on the major currency networks in international banking, we have also generated versions of Graphs 1-3, which take account of both, the bilateral currency share and the size of the bilateral lending relationship. Those additional graphs are displayed in Appendix A.

4. Analysis: the case of taper tantrum

We investigate the importance of currency networks in international banking by examining an event, the US taper tantrum, which likely had a unique impact on the largest one network, the US dollar network. An advantage of this methodology is that it can be generalised to study the impact of other events on various cross-border bank lending currency networks. For example, it can be used to examine the effect of the announcements of the 2015 ECB QE programme on the euro network and of the 2013-14 Japanese QE programmes on the Japanese yen network.

Descriptive statistics

During the taper tantrum of Q2-Q3 2013, the rate of contraction in cross-border bank claims deepened considerably (Table 4). Lending was already slowing before the taper tantrum, falling by roughly 2.7% in the preceding two quarters (first row, second column). Following the Federal Reserve's taper announcement in May 2013, the pace of contraction fastened to 4.1% (first row, first column) – that is lending decelerated by around 1.4% during the taper tantrum (first row, third column).

The general lending dynamics differed further across two dimensions: currency and borrowing country groups. First, dollar lending decelerated less sharply (by 1.0%) than non-dollar lending (by 1.6%) (Table 4, second and third rows, third column). This is not fully surprising: much of the dollar lending was directed to countries which act as safe havens during stress periods - most eminently the United States, which accounted for around one-half of global US dollar cross-border claims (fourth column).

Second, the impact of the taper tantrum differed distinctly among three groups of borrowers. First, lending to the United States actually picked up (by 3.3%) during

the taper tantrum. Second, lending to advanced economies outside of the U.S. decelerated slightly (by 2.1%) during the same period. Finally, emerging markets experienced a very sharp slowdown in cross-border bank lending. EME borrowers experienced a deceleration (of 8.9%) which was more than four times larger than that to advanced economies outside of the US.

Cross-border bank lending during taper tantrum

Table 4

	Flows during taper tantrum episode (%)[1]	Flows before taper tantrum episode (%)[2]	Deceleration through taper tantrum (%)[3]	Amounts outstanding, Q3 2012[4]
All borrower countries				
All currencies	–4.1	–2.7	–1.4	21.6
US dollar	–1.9	–0.9	–1.0	8.3
Other currencies	–5.5	–3.9	–1.6	13.3
United States				
All currencies	–0.8	–4.2	3.3	4.6
US dollar	0.0	–2.7	2.8	3.9
Other currencies	–5.5	–12.1	6.6	0.7
Other advanced economies[5]				
All currencies	–5.6	–3.6	–2.1	15.5
US dollar	–5.0	–2.1	–2.9	3.7
Other currencies	–5.8	–4.0	–1.8	11.8
Emerging markets[6]				
All currencies	1.4	10.3	–8.9	1.6
US dollar	3.5	15.4	–11.9	0.7
Other currencies	–0.5	5.7	–6.3	0.8

[1] Sum of exchange rate adjusted cross-border bank lending flows during Q2 and Q3 2013 as a percentage of amounts outstanding at the end of Q3 2012. [2] Sum of exchange rate adjusted cross-border bank lending flows during Q4 2012 and Q1 2013 as a percentage of amounts outstanding at the end of Q3 2012. [3] The difference between the first and second column in percentage points. [4] Cross-border bank lending, amounts outstanding at the end of Q3 2012, in trillions US dollars. [5] Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, Malta, the Netherlands, New Zealand, Norway, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom. [6] Angola, Bulgaria, Brazil, Chile, China, Chinese Taipei, Croatia, Czech Republic, Hungary, India, Israel, Korea, Liberia, Lithuania, Marshall Island, Mexico, Morocco, Nigeria, Poland, Romania, Russia, South Africa, Turkey, Ukraine and Vietnam.

Source: BIS international banking statistics.

Furthermore, dollar lending behaved very differently across the above three borrower groups. In the case of EME borrowers, the rate of deceleration in dollar lending (11.9%) was almost double that for lending in other currencies (6.3%). US-dollar denominated lending to advanced economies other than the U.S. also decelerated by more than lending in other currencies to the same set of borrowers, although the difference was not as large as in the case of EMEs (-2.9% versus -1.8%, respectively). By contrast, US dollar lending to the United States accelerated by 2.8% during the taper tantrum.

Potential drivers of cross-border bank lending

While our main interest is the behaviour of currency networks and their effect on cross-border bank lending, we need to control for non-currency related drivers of bank lending flows. Economic theory and past studies (McGuire and Tarashev (2008),

Takáts (2010), De Haas and Van Horen (2012), Van Rijckeghem and di Mauro (2013), Cerutti et al (2015), Cetorelli and Goldberg (2011), Avdjiev and Takáts (2014)) of cross-border bank lending suggest a number of economic variables as possible non-currency related drivers of cross-border bank lending. To limit arbitrary data selection, we start our examination with the wide range of potential explanatory variables identified in Avdjiev and Takáts (2014). Furthermore, we give equal consideration to lending banking system and borrowing country related factors as potential drivers.

We explore three lending banking system variables: the change in the average bank CDS spread, past credit and deposit growth in the home market. A rise in the CDS spread of the lending bank during the taper tantrum could potentially signal increased levels of bank stress, which would in turn reduce banks' ability to lend. From a different perspective, rapid credit or weak deposit growth in the home market could be a predecessor of subsequent funding strains.

We also examine three borrowing country variables: current account balance, government budget balance, and cumulative real credit growth to the private sector. Higher current account and budget deficits make borrowers more vulnerable, which typically would reduce banks' willingness to lend. Meanwhile, the impact of rapid real credit growth over a medium term horizon is more ambiguous. On the one hand, the relationship can be positive: very weak credit growth might be associated with economic underperformance and thereby imply less resilient cross-border bank lending. On the other hand, excessively strong credit growth might stretch the balance sheets of local borrowers and make them more exposed to external shocks (BIS, 2014b) - which would reduce banks' willingness to supply cross-border credit to these overstretched borrowers.

In addition to these factors, we also add the share of lending in the currency of interest: the share of dollar during the taper tantrum, the euro during the ECB QE and the yen during the Japanese QE. For instance, when examining the taper tantrum we control for the share of US dollar lending in the bilateral lending relationship, ie from each lending banking system to each borrowing country.

Regression analysis

The previous descriptive statistics suggests that bank lending within the dollar network held up better than lending in other currencies in general. However, this pattern seems to have reversed in lending to emerging markets: there dollar lending did perform worse than lending in other currencies. The question is whether these raw, unconditional correlations hold after controlling for other potential drivers. Hence, we undertake a regression analysis to control for other potential drivers of cross-border bank lending and thereby confirm that the observed pattern is indeed linked to the dollar network.

Our regression analysis on the taper tantrum is building on Avdjiev and Takáts (2014) which explicitly analysed the drivers of cross-border bank lending during the taper tantrum. As the BIS bank lending data is reported at a quarterly frequency and the taper tantrum lasted from May to September 2013, we compare the growth rates in cross-border bank lending in Q2 and Q3 2013 to their counterparts in the preceding two quarters (Q4 2012 and Q1 2013). In other words, we focus on the second derivative (ie the acceleration or deceleration) of cross-border bank lending during the taper tantrum.

Furthermore, we weigh each observation by the size of the respective bilateral stock of outstanding cross-border claims at the end of Q3 2012. More specifically, the weight that we assign to each observation is equal to the ratio of the respective bilateral stock to the sum of all bilateral stocks in our sample. Economic logic and our examination of the data suggest that smaller volumes tend to be highly volatile as they can reflect more bank-specific, or even project-specific, factors. Consequently, the evolution of larger bilateral cross-border bank lending claims is likely to reflect changes in the economic environment more accurately. In order to control for extreme outliers, we also winsorise the dependent variable at the 1% and the 99% levels and exclude observations for which the value of the dependent variable is more than five standard deviations away from the mean of the winsorised sample.

We select our benchmark explanatory variables through an elimination process. We start by running a panel regression which includes all six candidate explanatory variables discussed in the previous section and the share of USD lending to borrowing countries. Given that the United States is the home country for the US dollar, we interact the bilateral USD share variable with a dummy for the United States as a borrowing country. In addition, given the potential emerging market link we add a dummy variable for emerging market economies and further interact it with other borrowing country variables. We use this admittedly large regression as a starting point to exclude the variable with the lowest t-statistic. Next, we re-run the regression with the remaining variables. We continue this iteration until all remaining explanatory variables are statistically significant at the five percent level.

Our benchmark regression, obtained through the above elimination process, explains the evolution of bilateral cross-border bank lending flows with the degree of stress experienced by the lending banking system (as proxied by lending banking system deposit and credit growth) and with the characteristics of the borrowing country (as proxied by the borrowing country government budget balance). In addition, we include the share of bilateral cross-border bank lending denominated in US dollars interacted with (i) a dummy for borrowers in the United States and (ii) a dummy for borrowers in emerging markets.[12] Formally, we estimate the following benchmark equation:

$$\Delta XBC_{b,l} = c + \alpha CreditGrowth_l + \beta DepositGrowth_l + \gamma BudgetBalance_b + \delta US_b USDshare_{b,l} + \phi EME_b USDshare_{b,l} + \varepsilon_{b,l} \quad (1)$$

Our dependent variable $\Delta XBC_{b,l}$ represents the change in the average growth rate of lending banking system *l*'s cross-border claims on borrowing EME *b* between the taper tantrum (Q2 and Q3 2013) and the two quarters preceding it (Q4 2012 and Q1 2013). Formally:

$$\Delta XBC_{b,l} = \frac{1}{2}\left(\frac{flow2Q13_{b,l}}{stock3Q12_{b,l}} + \frac{flow3Q13_{b,l}}{stock3Q12_{b,l}}\right) - \frac{1}{2}\left(\frac{flow4Q12_{b,l}}{stock3Q12_{b,l}} + \frac{flow1Q13_{b,l}}{stock3Q12_{b,l}}\right)$$

Our independent variables are defined as follows: *c* is a constant; $CreditGrowth_l$ is real credit growth to the non-financial private sector in 2012 in lending banking system *l* (in percent); $DepositGrowth_l$ is real deposit growth in 2012 in lending banking system *l* (in percent); $BudgetBalance_b$ is the balance of the general

[12] The benchmark regression specification deviates from the one used in Avdjiev and Takáts (2014), which focused solely on EME borrowers. This is expected: since lending to EMEs represents only around 10% of global cross-border bank lending, its drivers can differ somewhat from global drivers.

government budget in 2012 in borrowing country *b* (in percent of GDP); $USDshare_b$ is the share cross-border bank lending denominated in US dollars from lending country *l* to borrowing country *b* (as of end-September 2012); US_b is a dummy for borrowers in the United States; EME_b is a dummy for borrowers in emerging markets and $\varepsilon_{b,l}$ is the error term. We weigh each observation *b,l* by the share of cross-border claims that lending banking system *l* had on borrowing EME *b* in total cross-border bank lending (across all borrower-lender pairs) in our sample as of end-March 2013 (the weight variable is not shown in equation (1) to ease the overview).

The results show that both lending banking system and borrowing country factors were statistically and economically significant drivers (Table 5). The benchmark regression explains around five percent of the total variation – a good fit for a large and very heterogeneous sample. All but one of the estimated coefficients are strongly statistically significant at the 1% level – and the only exception is also very close with a p-value of around 1.2%. Thus, all estimated coefficients in our benchmark specification easily clear the 5% significance threshold used to narrow down the list of variables.

Regression results

Table 5

Variables	Coefficient[1]	*t*-statistic	Probability
Lending banking system credit growth $(CreditGrowth_l)$	–2.99	–4.77	0.0000
Lending banking system deposit growth ($DepositGrowth_l$)	2.31	2.53	0.0116
Borrowing country budget balance $(BudgetBalance_b)$	1.93	2.88	0.0041
US borrower - USD share interaction $(US_b*USDShare_b)$	0.38	5.11	0.0000
EME borrower – USD share interaction $(EME_b*USDShare_b)$	–0.66	–4.22	0.0000
R-squared (in %)	5.05		
Number of observations	1217		

[1] All coefficient estimates are multiplied by 1,000 to ease representation.

Source: Authors' calculations.

The sign of the estimated coefficient for the lending banking system credit growth (α) variable is negative as expected. The negative coefficient implies, that stronger credit growth over the past year is associated with a greater reduction in cross-border bank lending by the respective banking system. The result is consistent with the intuition that past credit growth can stretch banks' balance sheets and thereby weaken their future cross-border lending in the face of negative shocks.

The sign of the estimated coefficient for the lending banking system deposit growth (β) variable is positive. The positive coefficient implies that stronger deposit growth over the past year is associated with more resilient cross-border bank lending performance (ie a smaller deceleration or a larger acceleration) by that banking system during the taper tantrum. This is consistent with the intuition that banks with a solid deposit base are better positioned to withstand negative funding shocks without resorting to large cuts in lending.

The coefficient on borrowing country government budget balance (γ) is positive, implying that a higher government budget surplus in a country is associated with more resilient cross-border bank lending growth to its residents. This is consistent with the intuition that the healthiness of public finances and economic prospects are positively correlated – economies with healthier public finances are more likely to have resilient credit demand during stress periods.

The coefficient on the interaction term between the United States borrower dummy and the share of US dollar lending (δ) is positive. This implies that a higher share of US dollar-denominated cross-border claims on the United States in a bilateral lender-borrower relationship was associated with more resilient cross-border lending for that relationship. In other words, lending to the United States acted as a safe haven during the taper tantrum and banking systems which had stronger US currency exposure increased lending to the United States more. Since the stock of USD denominated claims on the United States alone was higher than the respective stock claims on all EMEs combined, this result largely explains much of the overall resilience of US dollar denominated lending.

By contrast, we obtain the opposite result when we interact the dollar lending share variable with the emerging market borrower dummy (ϕ): the coefficient turns negative. This means that – in contrast to the United States - emerging economies with larger dollar share in their external bank financing were seen as vulnerable. In other words, whereas a high dollar share was linked with safe haven flows to the United States, it was associated with flight from emerging markets.

Importantly, when not interacted with either the United States or the emerging market dummy, the USD share variable is not significant. For this reason the standalone USD share variable is not incorporated in the benchmark regression. However, its insignificance has an important implication: namely that the US dollar share did not affect lending to other advanced economies outside the United States.

Economic significance

The empirical exercise in the previous section identified the main drivers of cross-border bank lending during the taper tantrum. In this section, we complement the analysis by quantifying the economic significance of the variables in our benchmark regression. We do that by decomposing the predicted decelerations in cross-border lending into contributions associated with the above drivers. This allows us to estimate the shares of the overall variation in the deceleration in cross-border bank lending accounted for by each driver. In addition, we estimate of the main drivers of the taper tantrum decelerations for individual lending banking systems and borrowing countries.

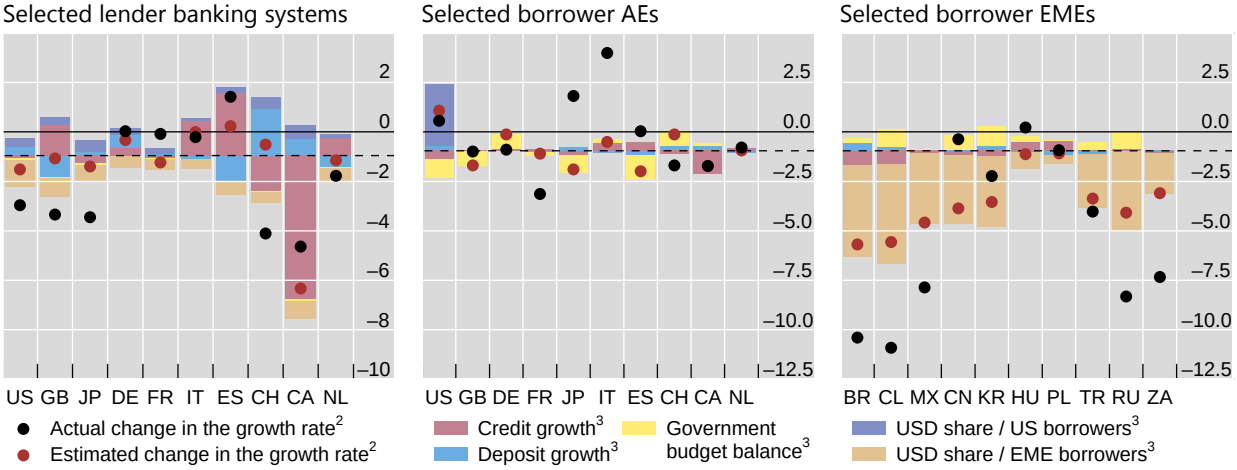
In our decomposition, we focus on deviations from means as in Avdjiev et al (2012) and Avdjiev and Takats (2014). More specifically, we first create demeaned variables by taking the difference between the regression variables in our benchmark equation and their respective means. We then calculate the contributions of the explanatory variables by multiplying the demeaned variables by the respective estimated coefficients.

According to our estimates, the US dollar share is the leading determinant of the variation in the deceleration in cross-border lending across lender-borrower pairs. The two (US and EME dummy-interacted) US dollar share variables jointly account for nearly half (44%) of the explained variation across all countries. More concretely, the US-interacted US dollar share explains 23% while its EME-interacted counterpart is responsible for 21%. The remaining three factors jointly account for slightly over one half of the explained variation. The share assigned to the lending banking system credit growth is close to a quarter (24%) and that of the borrowing country budget balance is just under a fifth (18%). Finally, the lending banking system deposit growth accounts for 14% of the explained variation.

Our estimates fit well for lending banking systems (Graph 4, left-hand panel). The estimated change in growth rates (red dots) are not very far from the actual changes (black dots). This suggests that, even though our regression does not capture all bilateral changes perfectly, lending banking system level aggregates fit reasonably well. In particular, our estimates capture the majority of the sharp slowdown in lending by Canadian banks, the mild deceleration reported by US and Dutch banks and the relatively unchanged behaviour of Italian and German banks. However, the estimates exhibit a slightly looser fit for some other lending banking systems such as Switzerland.

Decomposition of the change in growth rate of cross-border bank lending[1]

In percentage points — Graph 4



BR = Brazil; CA = Canada; CH = Switzerland; CL = Chile; CN = China; DE = Germany; ES = Spain; FR = France; GB = United Kingdom; HU = Hungary; IT = Italy; JP = Japan; KR = Korea; MX = Mexico; NL = the Netherlands; PL = Poland; RU = Russia; TR = Turkey; US = United States, ZA = South Africa.

[1] Change in the average growth rate of cross-border bank lending to EMEs between Q2–Q3 2013 and Q4 2012–Q1 2013. [2] The reported actual and estimated changes in the growth rates for individual lending banking systems and borrowing countries represent weighted averages of the respective bilateral changes, weighted as in the benchmark regression equation (ie by the size of the respective bilateral stock of outstanding cross-border claims at the end of Q3 2012). The individual changes in the growth rates reported in the graph may differ from the respective changes obtained from alternative data sources due to the fact that the new Stage I data set is not yet fully complete (see main text for further details). [3] As defined in the benchmark regression.

Sources: IMF, *International Financial Statistics*; Datastream; BIS locational banking statistics by nationality; national data; BIS calculations.

The bulk of the explained variation across lending banking systems is due to the factor which captures the intensity of past credit growth in their respective home countries (red bars). The second variable on the lending banking system side, past deposit growth, has a considerable positive effect in the case of Canadian and Swiss banks and sizeable negative impact in the case of Spanish and UK banks. The remaining factors are not as important in explaining the variation across lenders (yellow, blue and beige bars). In other words, the results suggest that the behaviour of lending banking systems were best explained by their own characteristics and not by the characteristics of the countries to which they have extended credit. This is intuitive – unless the foreign portfolio of a given lending banking system is heavily concentrated on borrowers with very similar characteristics, the borrowing country factors would tend to offset each other in the aggregate.

The estimates for borrowing countries show a somewhat looser fit (Graph 4, centre and right-hand panel). Among advanced economies, the estimates are close to actual changes for the larger borrowing countries, such as the United States, the

United Kingdom and Germany (centre panel). However, our regression does not fully capture the deceleration in lending to France or the acceleration in lending to Japan and Italy. Though emerging markets are smaller, and thus would carry smaller weights in our estimates, the fit is remarkably tight for a number of them (see, for instance, Hungary, Korea, Poland, and Turkey). That said, our estimates do not fully explain the relative resilience in lending to China and the weakness in lending to Brazil, Chile, and Russia.

Finally, the decompositions by individual borrowing countries exhibit a sharp contrast among the three groups of borrowers discussed above (ie the U.S., non-U.S. AEs and EMEs). The US dollar share has a very large positive impact on US borrowers and no effect on borrowers in other advanced economies (Graph 4, centre panel, blue bars). By contrast, for the majority of EME borrowers, the impact of the US dollar share is negative and in, many cases, quite large (right-hand panel, beige bars). This factor shaves roughly five percentage points off the growth rate of lending to Brazil and Chile and approximately four percentage points off the rate for China, Korea, Mexico and Russia. Meanwhile, the negative impact of the US dollar share on lending to Hungary and Poland is very small since for both of these countries the dollar share is significantly below the mean for EME borrowers.

Sensitivity analysis

We examine the robustness of our benchmark results to alternative specifications by conducting a sensitivity analysis. While we do not list all the detailed regression results for the sake of brevity, they are available upon request.

The benchmark results are robust to the inclusion of additional explanatory variables as one would expect based on our elimination strategy. When we add one-by-one the other potential explanatory variables excluded in the elimination process, the benchmark regression remains robust and the new variable insignificant.

The benchmark results also remain robust to the exclusion of individual lending banking systems from the sample. The sign, size and statistical significance of the coefficient estimates remain robust in almost all cases. More precisely, the explanatory variables remain significant at the 5% level in all but two out of 135 possible coefficient estimates.[13] None of the two significance losses affect the USD share interaction terms with the United States and emerging markets – and thereby they do not affect our conclusions about the role of currency networks.

Furthermore, the benchmark results also remain robust to the exclusion of individual borrowing countries from the sample. The coefficients' signs remain unchanged in all cases. The explanatory variables remain significant at the 5% level in in all but one out of 250 possible cases.[14] Again, the significance loss does not affect the USD share interaction terms – and our results on the importance of currency networks.

We also confirm that the interaction term between the US dummy and USD share does not only pick up United States specific effects. When we re-run the regression with only the US dummy, the results weaken marginally, suggesting that our benchmark model is properly specified. Yet, the interaction term is close to a

[13] Credit and deposit growth are no longer significant once we exclude Canada.

[14] Deposit growth is no longer significant once we exclude the United Kingdom .

simple US dummy because the currency denomination is strongly driven by the borrowing country. Hence, some caution is warranted when interpreting the result on the US interaction term.

Finally, we provide additional evidence that using the new Stage 1 data is critical for our analysis. In particular, we demonstrate that running the benchmark regression with the dependent variable constructed using the consolidated data (the first row in Table 1) instead of the new Stage 1 data (the last row in Table 1) generates considerably different results. Most importantly, the interaction term between the United States and the USD share variable becomes insignificant. Furthermore, the GDP balance variable also becomes insignificant. Thus, a researcher using the consolidated data instead of the Stage 1 data would have (erroneously) concluded that the major difference lies between advanced economies and emerging markets without being able to identify the safe haven flows to the United States.

Lending to banks versus non-banks

In order to obtain a better understanding of the underlying mechanisms driving the above results, we examine the behaviour of the two main cross-border bank lending recipient sectors: banks and non-banks. More concretely, we re-estimate the benchmark regression presented in the previous section while replacing the original dependent variable (the change in bilateral cross-border lending to all sectors) with the change in cross-border bank lending to banks and non-banks, respectively.

More precisely, we focus on the following system of equations:

$$\Delta XBC^{B}_{b,l} = c + \alpha CreditGrowth_{l} + \beta BudgetBalance_{b} + \gamma USDshare^{B}_{b,l} + \phi EME_{b} USDshare^{B}_{b,l} + \varepsilon^{B}_{b,l} \quad (2)$$

$$\Delta XBC^{NB}_{b,l} = c + \alpha CreditGrowth_{l} + \beta BudgetBalance_{b} + \gamma USDshare^{NB}_{b,l} + \phi EME_{b} USDshare^{NB}_{b,l} + \varepsilon^{NB}_{b,l} \quad (3)$$

The superscripts (*B* and *NB*) in (2) and (3) indicate whether a given variable applies to lending to banks or non-banks, respectively. Note that in addition to the dependent variable, the USD share and the weight[15] in each of the above two equations are also sector-specific.

The dependent variables in the above two equations are defined in an analogous manner to their counterpart in the benchmark specification:

$$\Delta XBC^{S}_{b,l} = \frac{1}{2}\left(\frac{flow2Q13^{S}_{b,l}}{stock3Q12^{S}_{b,l}} + \frac{flow3Q13^{S}_{b,l}}{stock3Q12^{S}_{b,l}}\right) - \frac{1}{2}\left(\frac{flow4Q12^{S}_{b,l}}{stock3Q12^{S}_{b,l}} + \frac{flow1Q13^{S}_{b,l}}{stock3Q12^{S}_{b,l}}\right)$$

where $S=\{B;NB\}$.

[15] Just as in the benchmark equation, we weigh each observation in the two sector-specific equations by the share of cross-border claims that lending banking system *l* had on the respective (bank or non-bank) sector in borrowing EME *b* in total cross-border bank lending (across all borrower-lender pairs) to that sector in our sample as of end-Q3 2012. The weight variable is not shown in equations (2) and (3) for presentational convenience.

First, we estimate equations (2) and (3) separately, as in many studies in the existing literature. We find that the coefficient estimates for lending to banks are qualitatively similar to those from the benchmark regression. By contrast, the results for non-bank lending are markedly different - all variables except for the lending banking system credit growth lose their statistical significance (Table 6). In particular, the US-interacted and the EME-interacted USD share variables are statistically significant for lending to banks (left-hand columns), but insignificant in the case of lending to non-banks (right-hand columns).

Regression results: banks vs non-banks

Table 6

Variables	Banks			Non-banks		
	Coefficient[1]	*t*-statistic	Probability	Coefficient[1]	*t*-statistic	Probability
Lending banking system credit growth *(CreditGrowth$_l$)*	–3.45	–3.90	0.0001	–3.43	–3.38	0.0008
Lending banking system deposit growth (*DepositGrowth$_l$*)	4.01	2.97	0.0030	0.10	0.07	0.9413
Borrowing country budget balance *(BudgetBalance$_b$)*	4.14	4.36	0.0000	–0.12	–0.11	0.9150
United States - USD share interaction *(US_b*$USDShare_b$)*	0.98	8.16	0.0000	0.04	0.43	0.6681
EME – USD share interaction *(EME_b*$USDShare_b$)*	–1.01	–4.4	0.0000	–0.25	–1.15	0.2493
R-squared (in %)	8.62			3.13		
Number of observations	1067			1164		

[1] All coefficient estimates are multiplied by 1,000 to ease representation.

Source: Authors' calculations.

Next, we use a Seemingly Unrelated Regressions (SUR) framework to confirm that the differences between the coefficient estimates of equation (2) and (3), except for the lending banking system credit growth, are statistically significant (see details in the Appendix).

The above results suggest that majority of the explained variation in cross-border bank flows during the taper tantrum was due to interbank lending rather than lending to non-banks. For interbank lending, all benchmark explanatory variables are statistically significant and preserve their respective signs from the all-sector benchmark regression. Furthermore, the statistical significance of all coefficients in the interbank regression is higher than that of the coefficients from the benchmark regression. In contrast to interbank lending, only one of the benchmark coefficients remains statistically significant in the case of the lending to non-banks.

One possible explanation for the sectoral differences in the behaviour of cross-border bank lending is related to the core-periphery network structure of the modern global banking system (Bruno and Shin (2015b)). Banks with access to US dollar wholesale markets channel funds to banks in other parts of the world. The demand for this funding is, in turn, largely determined by the effective credit risk associated with lending to local borrowers. When the local currency weakens against the USD, the health of the balance sheets of local borrowers with currency mismatches deteriorates, resulting in higher credit risk, and hence, diminished bank lending capacity. Thus, the substantial depreciations of most EME currencies against USD that took place during the taper tantrum reduced the risk-taking propensity of regional EME banks, which in turn decreased their demand for cross-border

interbank funding. Therefore, our results provide evidence for the currency appreciation "risk-taking channel" described in Bruno and Shin (2015b).

5. Conclusion

Our paper undertakes two tasks. First, it maps the currency composition of cross-border bank lending. While the US dollar tends to dominate at a global level, the euro network is also highly relevant, especially for advanced and emerging Europe. The mapping also suggests that the borrowing country matters more for the currency composition than the lending banking system. In other words, the destination of cross-border bank lending is more important for the currency denomination of claims than the source.

Furthermore, the paper also shows that currency networks have a significant influence on cross-border bank lending. Our analysis of the taper tantrum shows that these currency effects are economically meaningful: the dollar share accounts for nearly one-half of the total explained variation in cross-border bank lending. In particular, the analysis demonstrates that higher dollar share was associated with (i) stronger lending to the United States, (ii) broadly unchanged lending to other advanced economies, and (iii) weaker lending to emerging markets. Finally, our analysis also reveals that this pattern is primarily shaped by interbank lending. By contrast, non-bank lending is not affected by the currency denomination of claims in a statistically significant manner.

The above findings have implications for the assessment of financial vulnerabilities. Namely, the results suggest that, when it comes to cross-border bank lending, the currency composition of claims matters *in addition* to the nationality of the lending banks. For instance, US dollar denominated lending from UK banks to emerging market banks suffered as the US prepared to tighten its monetary policy stance during the taper tantrum. Therefore, it may be beneficial for policymakers in emerging markets to monitor not only the quantity and sources of cross-border loans, but also their currency composition.

Of course, these tentative results need to be analysed further before arriving to any firm conclusions or policy recommendations. In particular, the results should be interpreted against the backdrop of the fact that cross-border bank flows represent only a part, albeit a considerable one, of international financial flows. While cross-border bank lending is important, non-bank cross-border financing has increased even more rapidly than cross-border bank lending over the past few years, as documented in BIS (2014b) and Chui at al. (2014). Hence, portfolio flows also need to be studied in the future to fully understand the workings of currency networks. That said, cross-border bank lending remains a major source of international financing, and hence understanding how currency networks could impact it remains essential for policy makers.

Finally, this analysis represents the first steps, and certainly not the final word, on currency networks in cross-border bank lending. Given their policy relevance, our first tentative results on the taper tantrum would hopefully motivate further studies on these networks. One clear line for such future research is to examine how the 2015 ECB QE announcement affected the euro network or how the 2013-14 Bank of Japan QE announcements impacted the yen network.

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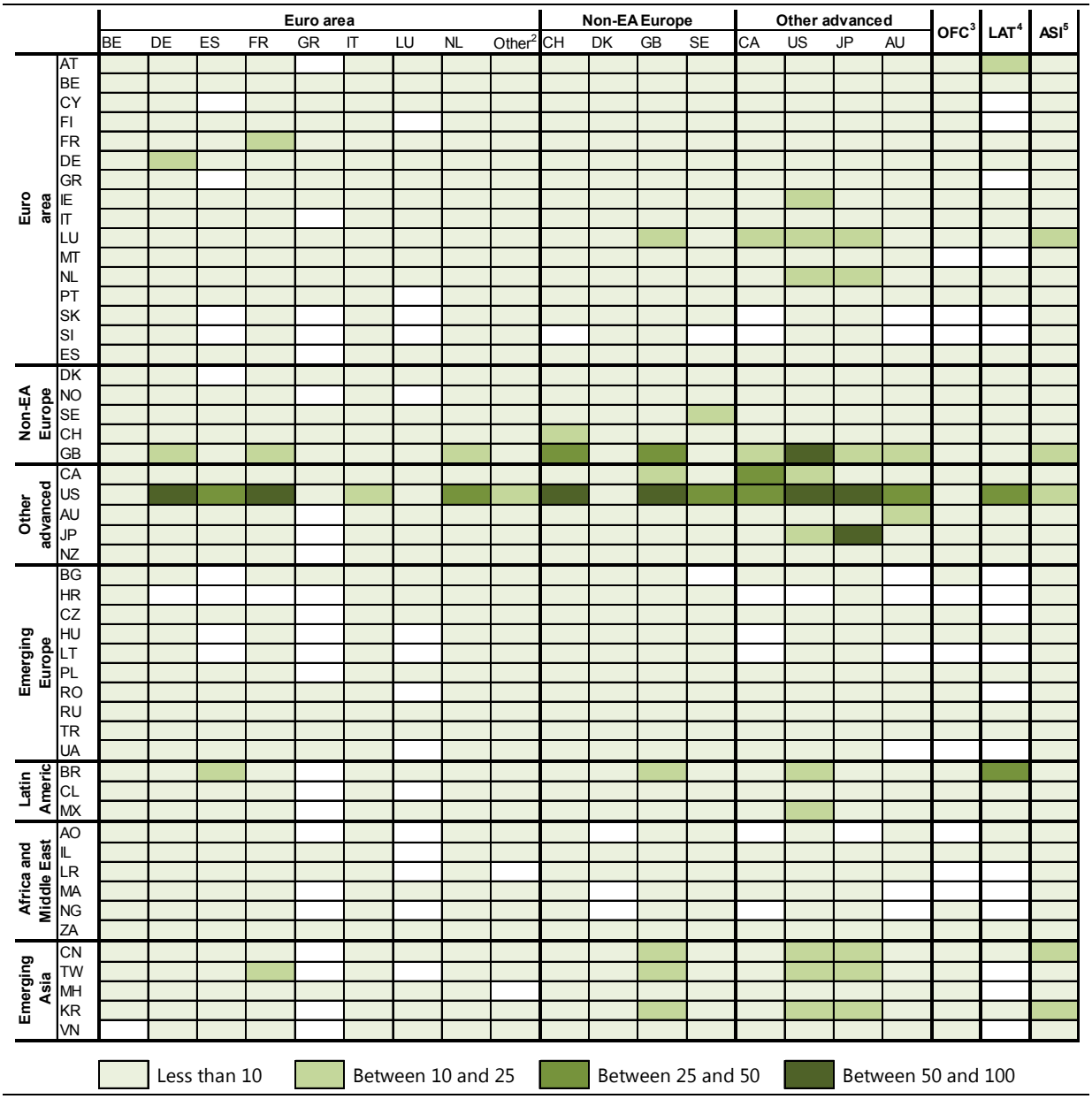
Appendix A: Currency network intensity heat maps

Intensity of US dollar denominated cross-border bank lending, end-Q4 2014

By nationality of lending bank (columns) and residence of borrower (rows), intensity score[1] Graph A-1



ASI = Emerging Asia; LAT = Latin America; OFC = Offshore centres.

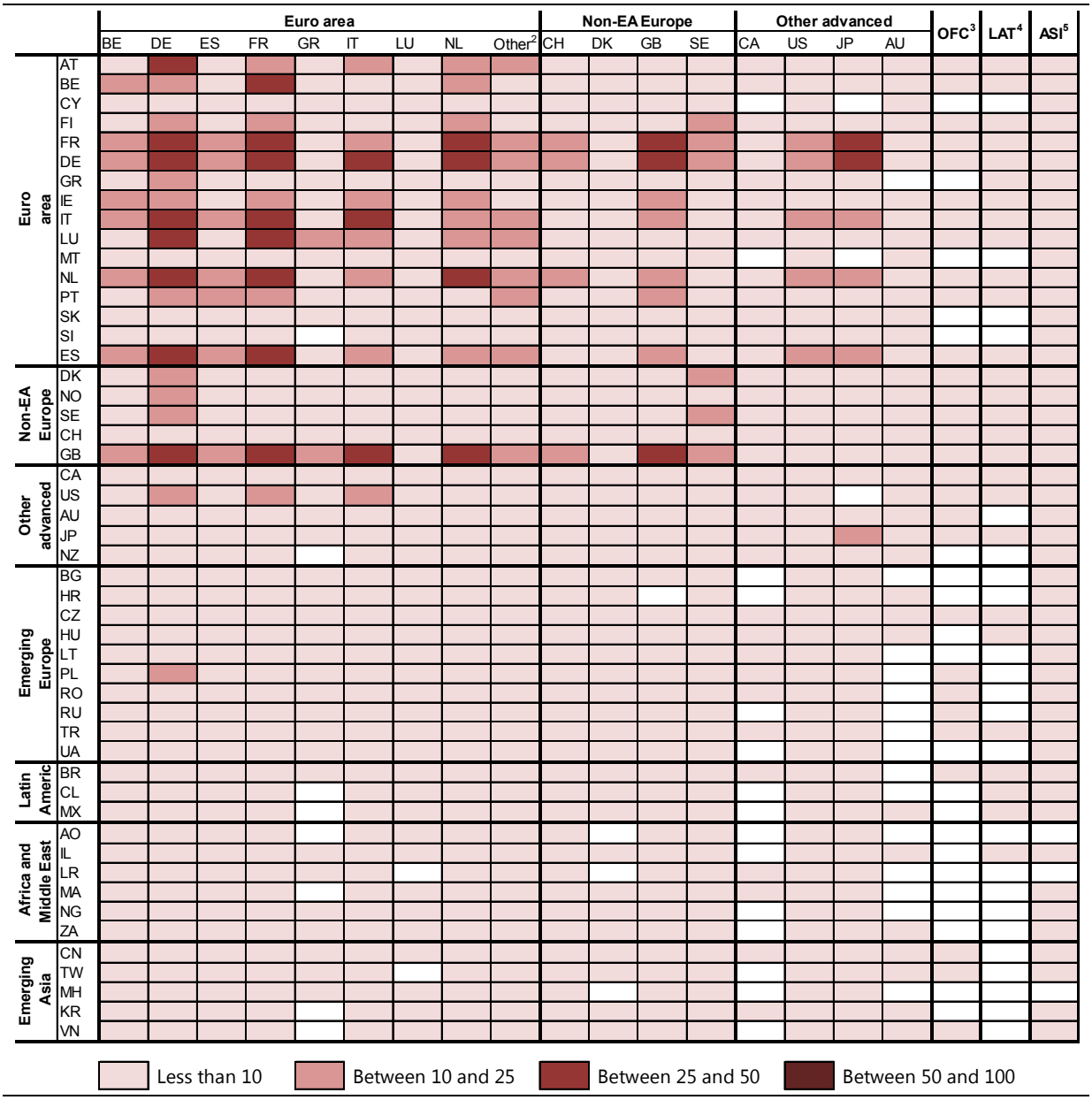
AO = Angola; AT = Austria; AU = Australia; BE = Belgium; BG = Bulgaria; BR = Brazil; CA = Canada; CH = Switzerland; CL = Chile; CN = China; CY = Cyprus; CZ = Czech Republic; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; FR = France; GB = United Kingdom; GR = Greece; HR = Croatia; HU = Hungary; IE = Ireland; IL = Israel; IT = Italy; JP = Japan; KR = Korea; LR = Liberia; LT = Lithuania; LU = Luxembourg; MA = Morocco; MH = Marshall Island; MT = Malta; MX = Mexico; NG = Nigeria; NL = the Netherlands; NO = Norway; NZ = New Zealand; PL = Poland; PT = Portugal; RO = Romania; RU = Russia; SE = Sweden; SI = Slovenia; SK = Slovakia; TR = Turkey; TW = Chinese Taipei; UA = Ukraine; US = United States; VN = Vietnam; ZA = South Africa.

[1] The intensity score for each pair ranges from 0 (least intense) to 100 (most intense) and is a function of the respective bilateral stock of outstanding claims and of the USD share for that pair. [2] Austria, Finland, Ireland and Portugal. [3] Hong Kong, Singapore and Panama. [4] Brazil, Chile and Mexico. [5] Chinese Taipei, India and Korea.

Source: BIS Stage 1 locational banking statistics by nationality.

Intensity of euro denominated cross-border bank lending, end-Q4 2014

By nationality of lending bank (columns) and residence of borrower (rows), intensity score[1] Graph A-2



ASI = Emerging Asia; LAT = Latin America; OFC = Offshore centres.

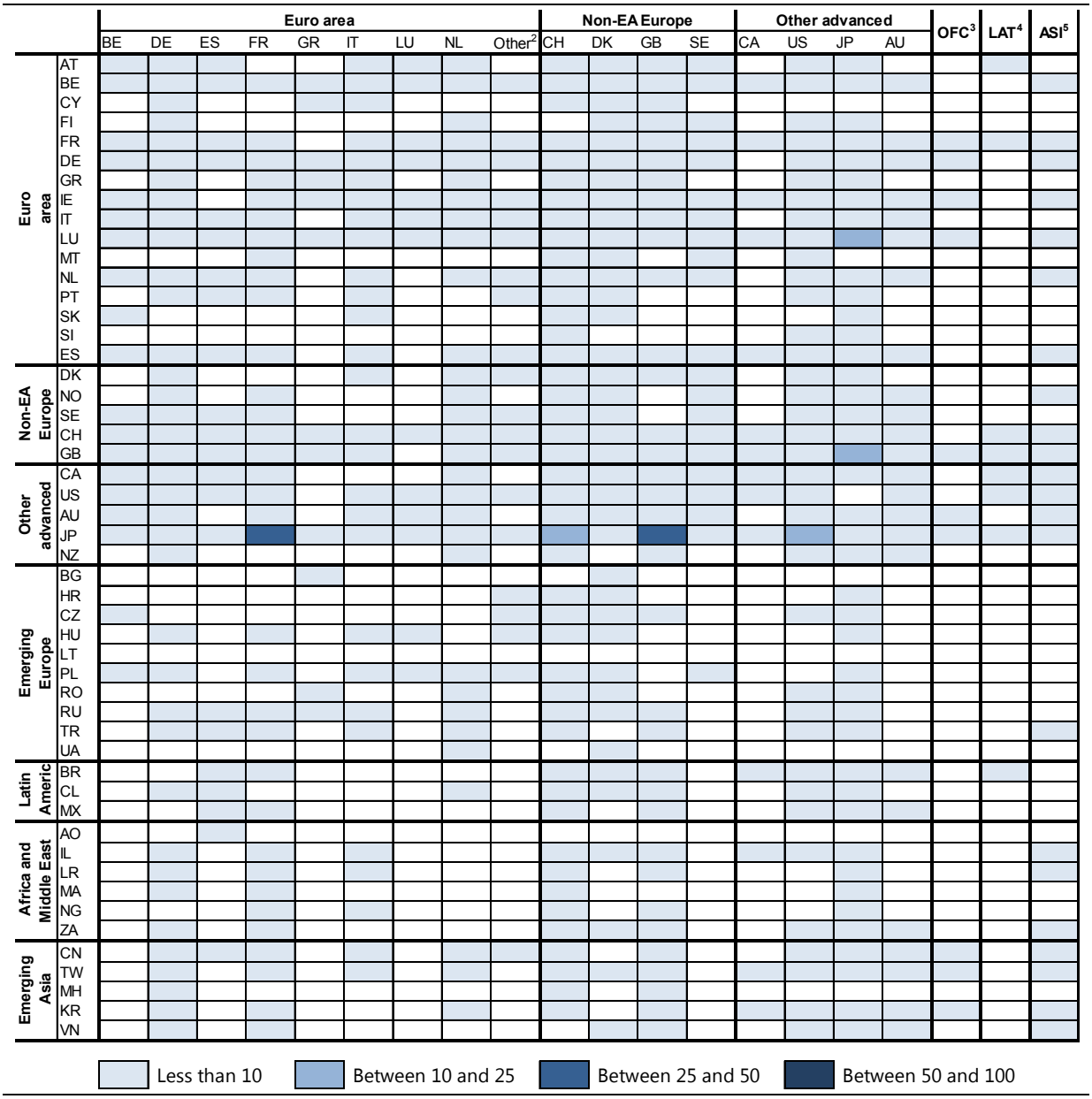
AO = Angola; AT = Austria; AU = Australia; BE = Belgium; BG = Bulgaria; BR = Brazil; CA = Canada; CH = Switzerland; CL = Chile; CN = China; CY = Cyprus; CZ = Czech Republic; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; FR = France; GB = United Kingdom; GR = Greece; HR = Croatia; HU = Hungary; IE = Ireland; IL = Israel; IT = Italy; JP = Japan; KR = Korea; LR = Liberia; LT = Lithuania; LU = Luxembourg; MA = Morocco; MH = Marshall Island; MT = Malta; MX = Mexico; NG = Nigeria; NL = the Netherlands; NO = Norway; NZ = New Zealand; PL = Poland; PT = Portugal; RO = Romania; RU = Russia; SE = Sweden; SI = Slovenia; SK = Slovakia; TR = Turkey; TW = Chinese Taipei; UA = Ukraine; US = United States; VN = Vietnam; ZA = South Africa.

[1] The intensity score for each pair ranges from 0 (least intense) to 100 (most intense) and is a function of the respective bilateral stock of outstanding claims and of the USD share for that pair. [2] Austria, Finland, Ireland and Portugal. [3] Hong Kong, Singapore and Panama. [4] Brazil, Chile and Mexico. [5] Chinese Taipei, India and Korea.

Source: BIS Stage 1 locational banking statistics by nationality.

Intensity of yen denominated cross-border bank lending, end-Q4 2014

By nationality of lending bank (columns) and residence of borrower (rows), intensity score[1] Graph A-3



ASI = Emerging Asia; LAT = Latin America; OFC = Offshore centres.

AO = Angola; AT = Austria; AU = Australia; BE = Belgium; BG = Bulgaria; BR = Brazil; CA = Canada; CH = Switzerland; CL = Chile; CN = China; CY = Cyprus; CZ = Czech Republic; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; FR = France; GB = United Kingdom; GR = Greece; HR = Croatia; HU = Hungary; IE = Ireland; IL = Israel; IT = Italy; JP = Japan; KR = Korea; LR = Liberia; LT = Lithuania; LU = Luxembourg; MA = Morocco; MH = Marshall Island; MT = Malta; MX = Mexico; NG = Nigeria; NL = the Netherlands; NO = Norway; NZ = New Zealand; PL = Poland; PT = Portugal; RO = Romania; RU = Russia; SE = Sweden; SI = Slovenia; SK = Slovakia; TR = Turkey; TW = Chinese Taipei; UA = Ukraine; US = United States; VN = Vietnam; ZA = South Africa.

[1] The intensity score for each pair ranges from 0 (least intense) to 100 (most intense) and is a function of the respective bilateral stock of outstanding claims and of the USD share for that pair. [2] Austria, Finland, Ireland and Portugal. [3] Hong Kong, Singapore and Panama. [4] Brazil, Chile and Mexico. [5] Chinese Taipei, India and Korea.

Source: BIS Stage 1 locational banking statistics by nationality.

Appendix B: Seemingly Unrelated Regressions

We use a Seemingly Unrelated Regressions (SUR) modelling framework to test whether the differences between the coefficient estimates of equation (2) and (3) are statistically significant. Applying the SUR framework also utilises additional information since the error terms in the two sectoral regressions (the one for lending to banks and the one for lending to non-banks) are not independent from each other because the dependent variables in the two sector-specific regressions sum up to the dependent variable from the benchmark (all-sectors) regression.

We apply the SUR procedure in several steps. First, we estimate the unrestricted system. That is, we estimate equations (2) and (3) independently of each other. We then test whether the estimated coefficients on each of the explanatory variables in the two sector-specific equations are equal to each other. Finally, we re-estimate equations (2) and (3) as a system, while restricting the pairs of coefficients whose differences are not statistically significant to be equal to each other.

We apply Wald tests to examine whether we can reject the null hypothesis that the coefficients are the same across equations (2) and (3). We apply the standard 5% threshold. While we cannot reject the null that the coefficients are the same for the lending banking system credit growth variable, the other three pairs of variables from the benchmark regression (the borrowing country government budget balance, and the USD share interactions with the US dummy and the EME dummy) are statistically different.

Based on the Wald test results, we estimate equations (2) and (3) as a system as follows. We restrict the coefficient on the lending banking system credit growth in the interbank equation to be the same as its counterpart in the non-bank equation. At the same time, we estimate all remaining coefficients without imposing any additional restrictions. The results generated by estimating the above SUR system confirm our findings from the separate estimation (Table A1).

System of linear equations: banks vs non-banks

Table A1

Variables	Banks			Non-banks		
	Coefficient[1]	*t*-statistic	Probability	Coefficient[1]	*t*-statistic	Probability
Lending banking system credit growth *(CreditGrowth$_l$)*	–3.45	–5.27	0.0000	–3.45	–5.27	0.0000
Lending banking system deposit growth (*DepositGrowth$_l$*)	4.01	3.53	0.0004	0.11	0.08	0.9334
Borrowing country budget balance *(BudgetBalance$_b$)*	4.14	4.87	0.0000	–0.12	–0.09	0.9253
US borrower - USD share interaction *(US$_b$*USDShare$_b$)*	0.98	9.13	0.0000	0.04	0.38	0.7041
EME borrower – USD share interaction *(EME$_b$*USDShare$_b$)*	–1.04	–4.91	0.0000	–0.25	–1.02	0.3100
R-squared (in %)	8.62			3.13		
Number of observations	1067			1164		

[1] All coefficient estimates are multiplied by 1,000 to ease representation.

Source: Authors' calculations.