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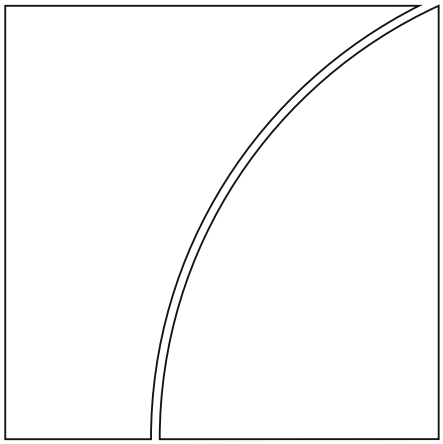

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Keywords: Currency networks; Cross-border banking flows; International monetary policy spillovers

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Monetary policy spillovers and currency networks in cross-border bank lending[1]

Stefan Avdjiev[2] and Előd Takáts[3]

We demonstrate that currency networks in cross-border bank lending have a significant impact on the size, distribution and direction of international monetary policy spillovers. Using the recently enhanced BIS international banking statistics, which simultaneously provide information on the lender, borrower and currency composition of cross-border bank claims, we map the major currency networks in international banking. Next, we show that during the 2013 Fed taper tantrum, exposure to dollar lending was associated with safe haven flows to the United States, virtually unchanged flow dynamics vis-à-vis other advanced economies, and strong outflows from emerging markets. Furthermore, this pattern was shaped by interbank lending rather than by lending to non-banks.

JEL classification: F34, G15, G21

Keywords: Currency networks; Cross-border banking flows; International monetary policy spillovers

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1. Introduction

The combination of exceptionally low interest rates and unconventional monetary policies implemented by advanced economy central banks in the aftermath of the Global Financial Crisis has generated a heated debate about cross-border monetary policy spillovers, focusing on the impact of interest rates in major currencies on global financial conditions, and on the possible transmission channels.

There is rapidly mounting evidence that monetary policy shocks in advanced economies are transmitted internationally and have a significant impact on global financial conditions. Rey (2013) has demonstrated the existence of a global financial cycle in capital flows, asset prices and in credit growth, which is primarily driven by US monetary policy. There is a common component in risky asset prices around the world (Miranda-Agrippino and Rey (2012)). Furthermore, capital flows are also highly correlated with one another and strongly negatively correlated with the VIX (Forbes and Warnock (2012)).

One of the most important channels through which monetary policy in advanced economies impacts global financial conditions is related to cross-border bank lending. Rey (2015) documents the international risk-taking channel of monetary policy, which operates though the unique role that the US dollar plays in international financial markets and international banking. Bruno and Shin (2015b) find evidence of monetary policy spillovers on cross-border bank capital flows and the US dollar exchange rate through the banking sector. Bruno and Shin (2015a) demonstrate that episodes of appreciation of the U.S. dollar are associated with deleveraging of global banks and an overall tightening of global financial conditions.

When analysing cross-border bank flows, the above studies have distinguished among the borrowing countries, but not among the nationalities of the lending banks and the currencies in which the flows are denominated. Both of the above dimensions are crucial. The *nationality* (ie the country of the headquarters) of the lending bank is a natural proxy for the decision making unit of the cross-border funds provider. As we demonstrate below, accounting for the share of external lending flows denominated in a given *currency* is essential for the proper empirical assessment of the cross-border spillovers generated by the monetary policy which controls the supply of that currency.

Historically, data limitations have prevented researchers from simultaneously using all three data dimensions which are needed to identify the major 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: the recently-enhanced BIS International Banking Statistics (IBS) simultaneously provide data on all three dimensions.

In this paper, we take advantage of the newly available dimensions in the enhanced IBS in order to conduct a more granular empirical examination of the international risk-taking channel of monetary policy. More concretely, 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 affect cross-border monetary policy spillovers through the banking system.

Our mapping identifies two large currency networks. The dollar network accounts for around one-half of all outstanding global cross-border bank claims. The euro network, which is primarily concentrated in the euro area and in emerging Europe, is

responsible for around one-third of global cross-border bank lending. The other currency networks, among which the largest is that of the Japanese yen, are much smaller than the dominant two. Our mapping also shows that the borrowing country is a more important determinant of currency choice than the lending banking system.[4]

In the second step of our project, we investigate whether the above currency networks have a significant impact on the international risk-taking channel of monetary policy. More concretely, the newly-available dimensions in the enhanced international banking data, which are available after Q2/2012, allow us to investigate the 2013 US Fed taper tantrum episode[5] as an example of a major US monetary policy shock, which had a large impact on global cross-border flows.

Our analysis suggests that currency networks have a significant impact on the size, distribution and direction of cross-border monetary policy spillovers. We find that exposure to the US dollar lending mattered during the taper tantrum episode, albeit not uniformly. At a global level, a higher share of US dollar claims in total claims was associated with stronger overall lending. Nevertheless, the aggregate numbers mask 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 outflows from emerging markets (EMEs). Furthermore, the impact of currency networks was 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. Our findings can be interpreted as evidence in support of the existence of the international risk-taking channel of monetary policy (Rey (2015) and Bruno and Shin (2015b)).

The results also 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. One possible explanation for this pattern is related to the core-periphery network structure of the modern global banking system (Bruno and Shin (2015a)). Banks with access to US dollar wholesale markets (ie "core banks") channel funds to banks in other parts of the world (ie "periphery banks"). 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 US dollar, 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 US dollar that took place during the 2013 taper tantrum reduced the risk-taking propensity of local EME banks, which in turn decreased their demand for cross-border interbank funding. We also formalise the above intuition in a stylised model.

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

[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.

[5] The "taper tantrum" starting in May 2013 with the Federal Reserve's hint that it might begin reducing its bond purchases sooner than previously expected. It triggered sharp drops of EME exchange rates, bond and equity prices.

the impact of currency networks on cross-border bank lending during the 2013 taper tantrum episode. The sixth section presents a stylised model that formalises the intuition behind our main empirical results. The seventh section concludes.

2. Related literature

In addition to the literature on cross-border monetary policy spillovers, our paper is also related three other strands of the international finance literature: (1) the literature on the drivers 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 denomination data dimension in it. There exists a rich literature on the drivers of gobal cross-border bank lending (eg De Haas and Van Lelyveld (2011), Rose and Wieladek (2011), Cetorelli and Goldberg (2012a), 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)). Our approach is closest to the one in Avdjiev and Takáts (2014), who use the enhanced BIS IBS data and explicitly consider borrowing country- and lending banking system-related drivers of cross-border bank lending. This paper extends the analysis in three dimensions by (i) broadening the scope of the analysis from borrowers in emerging market to borrowers in all countries, (ii) mapping currency networks and (iii) fully exploiting the newly-available currency composition data dimension in the empirical 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. Similarly to some of this FX lending literature, we also consider determinants of lending related to the borrowing country[6] and to lending banking system.[7] 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, in contrast to the existing literature, 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)).

Third, our approach also related to the nascent literature on the absence of a triple coincidence in international finance (Shin (2012) and Avdjiev et al (2015b)). More concretely, we explicitly build on and provide empirical support for the insight that national income boundaries, decision making units and currency usage realms

[6] 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)).

[7] 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.

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 financial conditions far beyond the borders of the country that issues it. For example, US monetary policy affects US dollar liquidity not only in the United States, but also globally (McCauley et al (2015)). 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 build on is related to the distinction between the decision making unit and national border. Namely, when investigating cross-border bank lending we focus on the nationality of the lending banking system and not on the residence of the lender – as the former is a much closer proxy for the relevant decision making unit. 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 makes a loan to its subsidiary in the United Kingdom, which then uses the funds to lend further to borrowers in the United States. What matters for the supply of cross-border lending in this example is the general health of the German banking system, and not that of the UK banking system. The fact that we focus on the nationality (rather than on the residence) of the lending bank allows us to classify the above transactions as an extension of credit from the German banking system to the United States (a link that would not appear in any residence-based statistic) and disregard the lending from Germany to the UK and from the UK to the US (the only links that would appear in a conventional residence-based statistic).

3. Data

Data on cross-border bank lending

To study the behaviour of 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 (dimension A) is the most obvious of the three. Naturally, the availability of this dimension is the most important pre-condition for the mapping of currency lending networks. Furthermore, when only outstanding stocks (but no flows) are reported, it is also necessary to control for the impact of currency fluctuations on changes in the outstanding stocks of cross-border bank claims.[8] 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 quarter-to-quarter changes in outstanding IBS claims, which are expressed in US dollars, also reflect currency movements and should be properly adjusted for that. The adjustment for currency movements is especially important in the context of our

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

empirical exercise because episodes of capital outflows from EMEs, such as the US taper tantrum, tend to coincide with large exchange rate movements.[9]

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 (dimension B). To identify lenders, we need to identify the nationality (ie the country of the headquarters) of the lending bank (dimension C), which is in turn a natural proxy for the decision making unit of the international bank.[10]

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 a loan to it subsidiary in the United Kingdom, which uses the funds to lend 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 look through the intermediate loans from the German parent bank to its subsidiary in the UK and from the UK subsidiary and the US borrower. To achieve this, we need the nationality of the banking system. A dataset which lacks 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 links (exactly the 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 a misleading picture on such links (Shin (2012)).

The second reason due to which we focus on the nationality (and not on the residence) of the lending bank is related to cross-border lending by banking units located outside of their home country to borrowers in their home country. These links are often substantial: for instance, foreign branches and subsidiaries of US banks held approximately $700 billion worth of claims on US residents as of end-2012. Once again, data on the nationality of the lending banking system is essential to identify these volumes: data based solely on the residence of lenders by definition could not show such links.

The recently implemented Enhancements to the BIS international banking statistics (IBS) provides the three necessary dimensions:[11]

A. the currency composition of cross-border claims,

[9] In fact, we demonstrate that correcting for exchange rate movements is crucial. If we were to use the consolidated data (which are not adjusted for currency fluctuations) instead of the enhanced IBS data (which are adjusted), then the results would differ considerably. Please see the Sensitivity analysis section for further details.

[10] Strictly speaking, the nationality of the lending bank identifies the home country of the highest level banking entity in the corporate chain, and not necessarily the decision making unit. In general, ownership and decision making are likely to overlap more closely in banking systems which are more centralised (eg German and French banks) than in those which are more decentralised (eg Spanish banks). Nevertheless, 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.

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

B. the residence of the borrower and

C. the nationality of the lending banking system.

The enhanced IBS data, which are available from Q2/2012 onwards, are the first 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 C) and on the residence of the borrower (dimension B), but did not contain a currency breakdown (dimension A). By contrast, the locational data by residence did have information on the currency composition of banks' cross-border claims (dimension A) and on the residence of the borrower (dimension B), but lacked information on the nationality of the lending bank (dimension C). 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
Enhanced 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 enhanced IBS data is not yet fully complete, it is fairly representative. On aggregate, information on the nationality of lending banks is available for more than 90% of global cross-border claims. However, this ratio varies 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 globally relevant lending national banking systems and borrowing countries, for which the quality and availability of the enhanced IBS data exceed a certain threshold. In particular, on the lending side, we include the 27 national banking systems whose home countries report both, Consolidated data and 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.[12]

At end-2014, the outstanding stock of BIS IBS cross-border bank claims totalled $28.5 trillion. Using the new dimensions in the enhanced IBS 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 12% 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 8% 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 ($0.4 trillion), EMEs ($0.4 trillion) and offshore centres ($0.2 trillion).

Cross-border bank claims at end-Q4 2014

In trillions of US dollars — Table 2

	Lender nationality		
	Advanced economies	Emerging Markets	Offshore centres
Borrower location			
Advanced economies	19.3	0.4	0.1
Emerging Markets	2.3	0.4	0.1
Offshore centres	3.5	0.2	0.1

Source: BIS international banking statistics.

4. Currency networks

More than three-quarters of global cross-border lending is accounted for by claims denominated in two major currencies: the US dollar and the euro. At end-2014, claims denominated in US dollars alone equalled $13.4 trillion, or 47% of the global total. Meanwhile, cross-border lending denominated in euros stood at $9.0 trillion, or 32% of the global aggregate. The third largest currency denomination, the Japanese yen accounted for only around 5% of the worldwide outstanding stock.

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

At the aggregate level, the above currency shares are roughly the same across counterparty sectors (Table 3, top panel). The US dollar shares of global cross-border lending to banks and non-banks are virtually the same at 47%. The same is true for the respective euro shares, both of which stand at 32% and 31%, respectively. In the case of the yen, the difference is more pronounced: cross-border lending to non-banks (6.6%) is almost twice as high as interbank lending (3.9%).

The dispersion in the currency composition of cross-border lending across borrowing locations is considerably larger (Table 3, bottom panel). In terms of lending to advanced economies, the US dollar and euro shares are roughly equal at 42% and 40%, respectively. Approximately half of US dollar-denominated bank lending to advanced economies (AEs) is accounted for by cross-border claims on residents of the United States ($4.2 trillion). Similarly, the majority of euro-denominated cross-border bank lending is directed towards borrowers in the euro area ($5.8 trillion) - and most of that amount represents intra-euro area cross-border claims ($3.8 trillion). Outside the United States, the euro area and Japan, the US dollar and the euro still dominate lending to advanced economies, albeit with smaller shares (37% and 30%, respectively).

Currency positions of cross-border bank lending at end-Q4 2014

In trillions of US dollars — Table 3

	Amounts outstanding				Percentage shares		
	All currencies	US dollar	Euro	Japanese yen	US dollar	Euro	Japanese yen
Counterparty sector							
All sectors	28.5	13.4	9.0	1.4	46.8	31.6	5.0
Banks, total	16.2	7.6	5.1	0.6	47.2	31.7	3.9
Non-bank, total	11.9	5.6	3.7	0.8	47.1	30.8	6.6
Counterparty countries							
Advanced economies	20.4	8.6	8.1	0.9	41.9	39.6	4.3
Euro area	8.1	1.4	5.8	0.2	17.7	71.7	2.5
Of which: intra – EA	4.3	0.3	3.8	0.0	7.5	89.3	0.3
United States	4.8	4.2	0.3	0.1	87.9	5.7	1.4
Japan	1.1	0.5	0.1	0.4	48.2	11.5	35.5
Other advanced	6.5	2.4	1.9	0.2	36.6	29.7	3.2
Offshore centres	4.0	2.7	0.3	0.5	66.6	8.1	11.6
Emerging markets	3.7	2.0	0.4	0.1	54.8	11.6	2.2
Emerging Europe	0.6	0.2	0.2	0.0	32.4	38.9	0.9
Latin America	0.6	0.5	0.0	0.0	75.4	4.1	1.5
Africa and Middle East	0.5	0.3	0.1	0.0	63.3	13.5	1.4
Emerging Asia	1.9	1.0	0.1	0.1	52.8	5.0	3.0

Source: BIS international banking statistics.

Lending to EMEs tends to be primarily denominated in US dollars as well: the dollar share (55%) is almost five times higher than the euro share (12%). Nevertheless, the aggregate EME numbers mask considerable variations across regions. The US dollar accounts for the majority of the claims on Latin America (75%), Africa and the

Middle East (63%) and emerging Asia (53%). Yet, it accounts for less than a third (32%) of the lending to emerging Europe. In fact, emerging Europe is the only EME region for which the euro is the leading currency, with around 39% of all claims. The share of yen is negligible, not exceeding 3% in any of the four EME regions.

The dominance of the US dollar is most pronounced in cross-border claims on offshore centres with a share of roughly two thirds (67%). Conversely, the respective share for the Japanese yen is merely 12%. 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 dollar share tends to be very high for banks headquartered in EMEs. By contrast, it is fairly low for euro area banks (particularly those headquartered in smaller countries), which tend to lend primarily in euros. Banks from larger advanced economies (eg US, UK, Germany France and Japan) tend to have cross-border lending portfolios which are more balanced across major currencies, albeit exhibiting a slight bias towards their home currency.

In order to explore the above heterogeneity, we use the enhanced IBS data to create global "heat maps" of bilateral cross-border lending shares for the three most used currencies: the US dollar, the euro and the Japanese yen. 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 mainly 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.

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

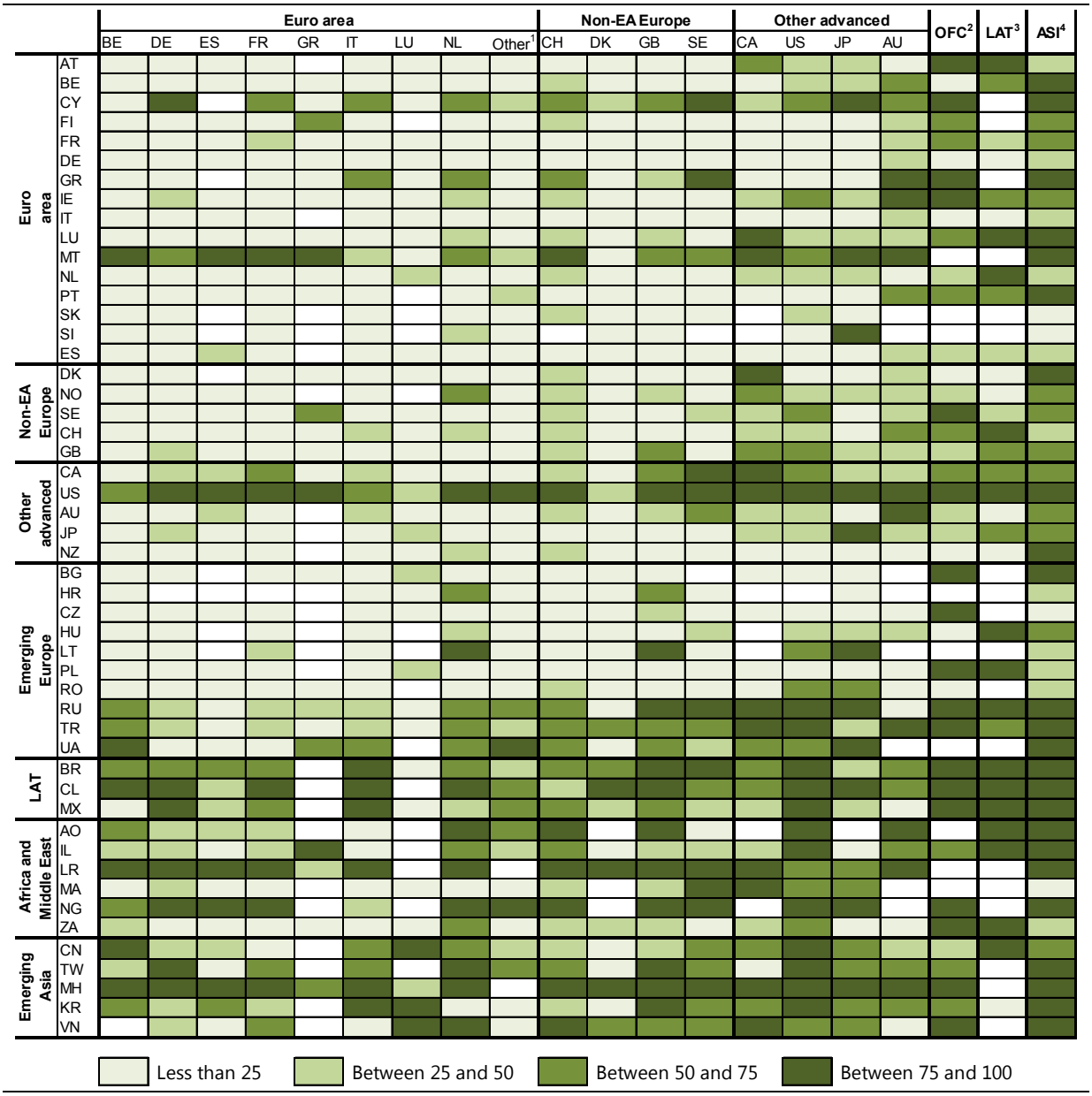
While very informative about the currency composition of the major bilateral cross-border bank lending relationships across the globe, the "heat maps" in Graphs 1-3 should be interpreted with the caveat that they do not reveal any information about the size the network nodes. For example, since they 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 the size issue we also generated versions of Graphs 1-3, which take into account both the bilateral currency share and the size of the bilateral lending relationship (Appendix A).

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.

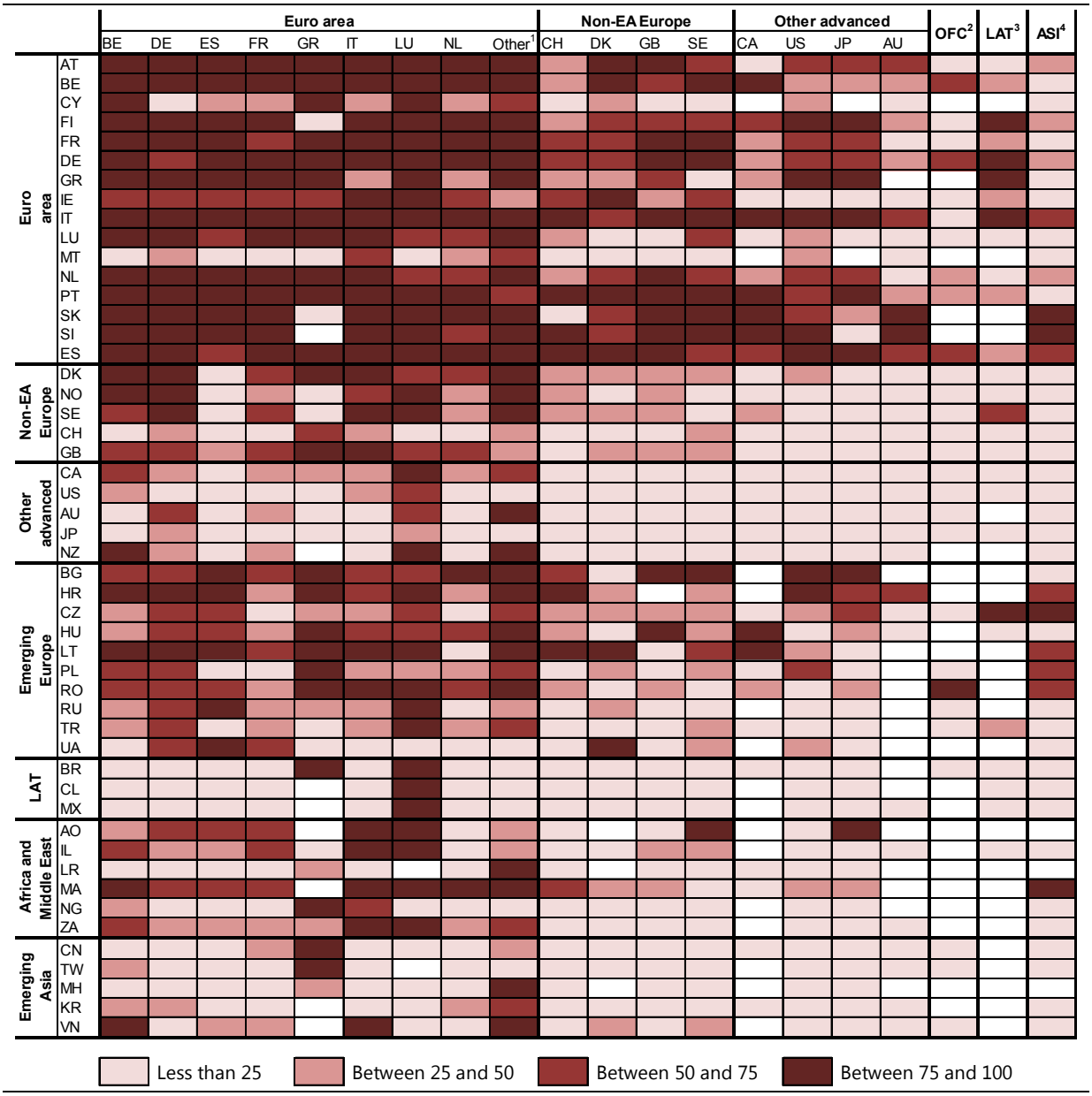
[1] Austria, Finland, Ireland and Portugal. [2] Hong Kong, Singapore and Panama. [3] Brazil, Chile and Mexico. [4] Chinese Taipei, India and Korea.

Source: BIS enhanced 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



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.

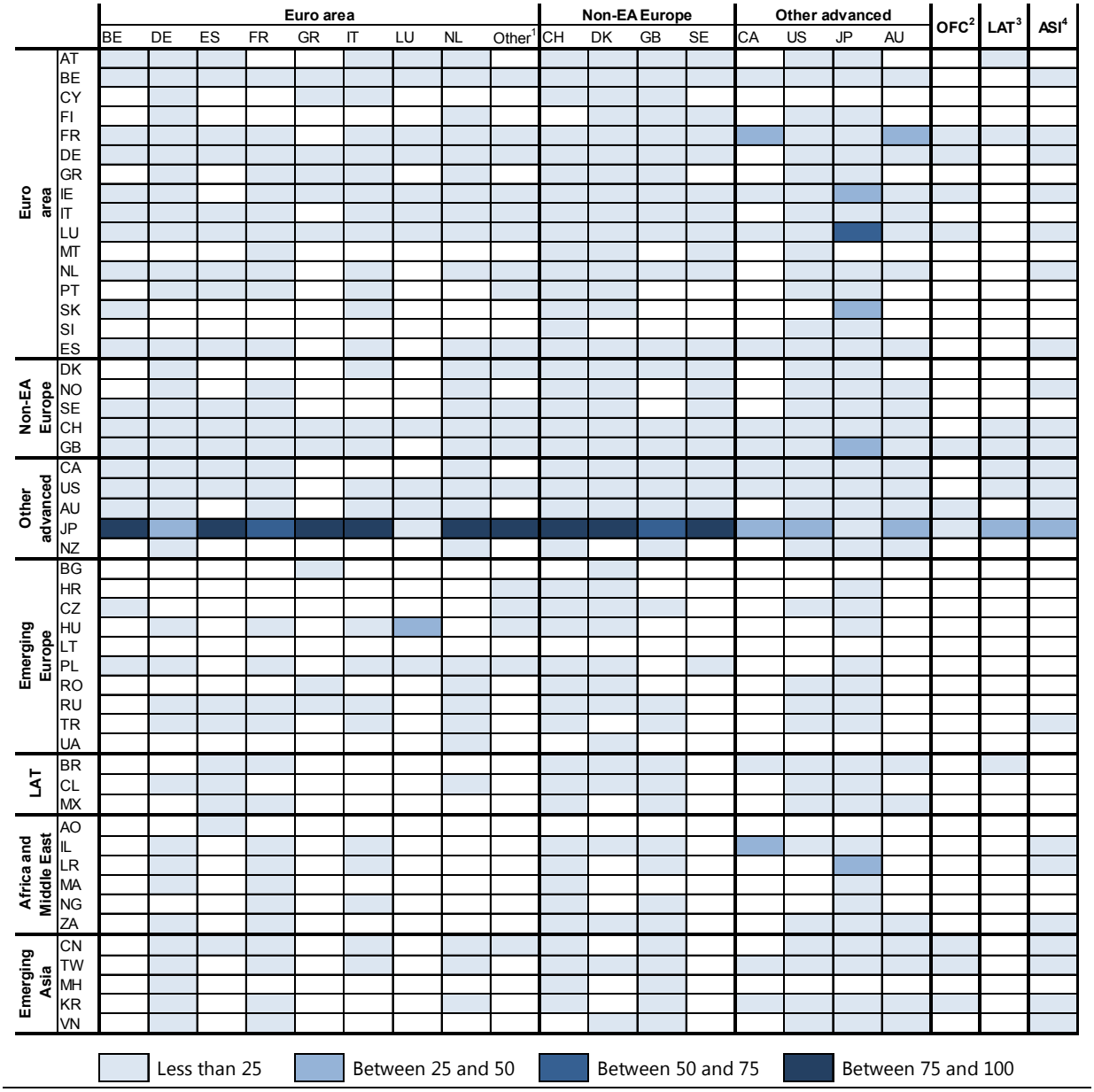
[1] Austria, Finland, Ireland and Portugal. [2] Hong Kong, Singapore and Panama. [3] Brazil, Chile and Mexico. [4] Chinese Taipei, India and Korea.

Source: BIS enhanced 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



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

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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 enhanced locational banking statistics by nationality.

5. 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 global currency network, the US dollar network. An advantage of the methodology we use is that it can be generalised to study the impact of other similar events such as the announcement 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 increased 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 increased 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 three dimensions: currency denomination, borrowing sector and borrowing country. In terms of currency denomination, the slower deceleration of dollar lending stands out. In aggregate, dollar lending decelerated by 1.0% as opposed to 1.6% for non-dollar lending (Table 4, second and third rows, third column). This is not entirely surprising: much of the dollar lending was directed to countries which act as safe havens during stress periods - most eminently to the United States (Table 4, fourth column).

Interestingly, during the taper tantrum, non-bank lending performed worse (decelerating by 3.6%) than interbank lending (which accelerated by 0.1%) (Table 4, fourth and fifth row). This is in sharp contrast to what took place during the global financial crisis, when the majority of the overall contraction in cross-border lending occurred in interbank markets. What makes this pattern even more remarkable is that interbank claims, which tend to have shorter maturities than claims on non-banks, are typically easier to adjust in response to changing circumstances.

In addition, the impact of the taper tantrum differed distinctly among three groups of borrowing countries. 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 saw a sharp deceleration in cross-border bank lending (of 8.9%).

Finally, dollar lending performed worse than non-dollar lending in all regions. Yet, regional lending dynamics exhibited substantial heterogeneity. In case of EME borrowers, both dollar and non-dollar lending decelerated sharply (by 11.9% and 6.3%, respectively). By contrast, lending to the United States accelerated both in dollars and in other currencies (2.8% and 6.6%, respectively). In other advanced economies, both dollar and non-dollar lending decelerated somewhat (2.9% and 1.8%, respectively).

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
Non-US dollar	–5.5	–3.9	–1.6	13.3
Bank borrowers	–4.6	–4.7	0.1	12.6
Non-bank borrowers	–3.1	0.5	–3.6	8.5
United States				
All currencies	–0.8	–4.2	3.3	4.6
US dollar	0.0	–2.7	2.8	3.9
Non-US dollar	–5.5	–12.1	6.6	0.7
Bank borrowers	5.8	–6.6	12.3	2.0
Non-bank borrowers	–6.1	–2.0	–4.0	2.5
Other advanced economies[5]				
All currencies	–5.6	–3.6	–2.1	15.5
US dollar	–5.0	–2.1	–2.9	3.7
Non-US dollar	–5.8	–4.0	–1.8	11.8
Bank borrowers	–7.3	–5.9	–1.4	9.7
Non-bank borrowers	–2.2	0.9	–3.2	5.3
Emerging markets[6]				
All currencies	1.4	10.3	–8.9	1.6
US dollar	3.5	15.4	–11.9	0.7
Non-US dollar	–0.5	5.7	–6.3	0.8
Bank borrowers	1.9	14.9	–13.0	0.8
Non-bank borrowers	0.7	5.6	–4.9	0.7

[1] Sum of exchange rate adjusted cross-border bank lending flows during the taper tantrum episode (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 the two quarters immediately preceding the taper tantrum episode (Q4 2012 and Q1 2013) as a percentage of amounts outstanding at the end of Q3 2012. [3] The difference between the sum of exchange rate adjusted cross-border bank lending flows during the taper tantrum episode (Q2 and Q3 2013) and the two quarters immediately preceding taper tantrum episode (Q4 2012 and Q1 2013) as a percentage of amounts outstanding at the end of Q3 2012. [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, Israel, Korea, Liberia, Lithuania, Marshall Island, Mexico, Morocco, Nigeria, Poland, Romania, Russia, South Africa, Turkey, Ukraine and Vietnam.

Source: BIS international banking statistics.

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 of cross-border bank lending (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)) suggest a number of economic variables as possible non-currency related drivers. To limit arbitrary data selection, we start our examination with the wide range of potential explanatory variables identified in Avdjiev and Takáts (2014). In this examination, we give equal consideration to lending banking system and borrowing country related factors as potential drivers.

We explore three lending banking system variables: (i) the change in the average bank CDS spread, (ii) past credit growth and (iii) past deposit growth in the home market. A rise in the CDS spread of the lending bank during the taper tantrum could 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 past real credit growth to the private sector. Higher current account and budget deficits make economies and the borrowers in them more vulnerable, which typically would reduce banks' willingness to lend when sentiment turns. 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 dollar lending in the bilateral lending relationship, ie from each lending banking system to each borrowing country.

Regression analysis

The previous descriptive statistics show that bank lending within the dollar network held up better than lending in other currencies in general. However, this pattern does not hold across individual borrowing regions. Hence, there is a clear need to investigate at the level of cross-border bank lending pairs (ie lending from individual lending banking systems to individual borrowing countries). Furthermore, one should 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 of the taper tantrum is building on Avdjiev and Takáts (2014), who explicitly analysed the drivers of cross-border bank lending to EMEs 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 (ie the variable shown in the third column of Table 4).

Furthermore, we weigh each observation by the size of the respective bilateral stock of outstanding cross-border claims at the start of the time window we examine (ie at end-September 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 reasoning 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.

In order to be as agnostic as possible about the main drivers of cross-border bank lending, we select our benchmark explanatory variables through a step-wise elimination process. We start by running a panel regression which includes all six candidate explanatory variables discussed in the previous section and the bilateral (ie lender-borrower pair-specific) share of USD lending. Given that the United States is the home country for the US dollar, we interact the bilateral USD share variable with a dummy for US borrowers. In addition, given the potential emerging market link (Milesi-Ferretti and Tille (2011) and Banerjee et al (2016)), we add a dummy variable for borrowers in emerging market economies and further interact it with other borrowing country variables and the USD share variable. We use this admittedly large regression as a starting point in our benchmark regression selection procedure. In each step, we eliminate the variable with the lowest t-statistic and 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 procedure, 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.[13] 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 growth rate of lending banking system *l*'s cross-border claims on borrowing country *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 private non-financial sector in the home country of lending banking system *l* during 2012 (in percent); $DepositGrowth_l$ is real deposit growth for lending banking system *l* in 2012 (in percent); $BudgetBalance_b$ is the 2012 general government budget balance of borrowing country *b* (in percent of GDP); $USDshare_b$ is the share cross-border bank lending denominated in US dollars from lending

[13] The benchmark regression specification deviates from the one used in Avdjiev and Takáts (2014), which focused solely on EME borrowers. This is not surprising - since lending to EMEs represents only around 10% of global cross-border bank lending, its drivers can differ somewhat from global drivers.

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 an error term. We weigh each observation b,l by the share of cross-border claims that lending banking system l had on borrowing country b in total cross-border bank lending (across all borrower-lender pairs) in our sample as of end-September 2012 (the weight variable is not shown in equation (1) to ease the overview).

Benchmark regression results

The benchmark regression shows that both lending banking system and borrowing country factors were statistically and economically significant drivers (Table 5). 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 potential explanatory variables.

Regression results

Table 5

Variables	Coefficient[1]	*t*-statistic	Probability
Lending banking system credit growth *(CreditGrowth$_l$)*	–0.299	–4.77	0.0000
Lending banking system deposit growth (*DepositGrowth$_l$*)	0.231	2.53	0.0116
Borrowing country budget balance *(BudgetBalance$_b$)*	0.193	2.88	0.0041
US borrower – USD share interaction *(US_b*USDShare$_{b,l}$)*	0.038	5.11	0.0000
EME borrower – USD share interaction *(EME_b*USDShare$_{b,l}$)*	–0.066	–4.22	0.0000
R-squared (in %)	5.05		
Number of observations	1217		

[1] All coefficient estimates are multiplied by 100 to ease representation.

Source: Authors' calculations.

The sign of the estimated coefficient for the past 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 rapid 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 (ie a smaller deceleration or a larger acceleration) 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 more fiscal space tend to be more resilient in the face of adverse external shocks (Kaminsky et al (2005)).

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. In other words, claims on the United States acted as a safe haven during the taper tantrum and banking systems which had greater dollar exposures 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 for that variable is negative and strongly significant. This implies that 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 away 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.

The above findings about the significance of the US dollar share in cross-border bank lending suggest that currency networks in cross-border bank lending impact the size, distribution and direction of cross-border monetary policy spillovers. In turn, this can be interpreted as evidence in support of the existence of the international risk-taking channel of monetary policy (Rey (2015) and Bruno and Shin (2015b)). We formalise the mechanism behind those results in a stylised model that we present in Section 6.

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 these drivers. We do that by decomposing the predicted decelerations in cross-border lending into contributions associated with these drivers – which in turn allows us to estimate the shares of variation explained by each driver.

In our decomposition procedure, 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.

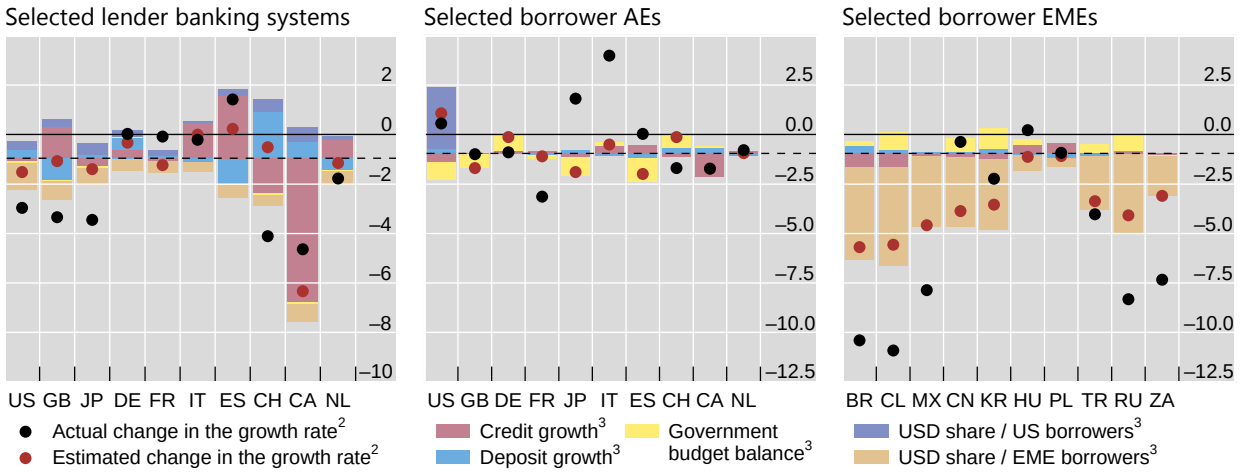
According to our estimates, the US dollar share is the leading determinant of the variation in the deceleration in cross-border lending across lender-borrower pairs. The two (US and EME dummy-interacted) US dollar share variables jointly account for nearly half (44%) of the explained variation across 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). Thus, 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. Nevertheless, 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 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 enhanced IBS 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 past credit growth variable (red bars). In addition, past deposit growth also explains considerable positive effect in for Canadian and Swiss banks and sizeable negative impact for 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.

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 the 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, the estimates do not fully explain the 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, the impact of the US dollar share for EME borrowers 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.[14]

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 newly-added 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.[15] None of the two significance losses affect the USD share interaction terms with the dummies for US and EME borrowers – 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.[16] Again, the significance loss does not affect the USD share interaction terms – and thereby the conclusions on currency networks.

[14] We do not detail all the regression results for the sake of brevity. Those are available upon request.

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

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

We also confirm that the interaction term between the US dummy and USD share does not only pick up US-specific effects. When we re-run the regression with only the (non-interacted) US dummy, the results weaken marginally, suggesting that our benchmark model is properly specified.

The results also remain robust to controlling for potential strategic considerations of lending banking systems. Following the approach of Cetorelli and Goldberg (2012b), we create a variable that measure the strategic importance of each borrowing country for each lending banking system. More specifically, we define the strategic importance variable as the share of cross-border claims that lending banking system X has allocated to borrowing country Y. Adding this strategic importance variable to our benchmark regression does not affect the benchmark results. The sign of that variable is positive as expected, i.e. the larger the share of a borrowing location in a lending banking systems' total cross-border claims, the more resilient the respective bilateral lending relationship is. Nevertheless, the coefficient is not significant at the standard 5% level.

Finally, we provide additional evidence that using the enhanced IBS data is critical for our analysis. In particular, running the benchmark regression with the dependent variable constructed using the consolidated data (the first row in Table 1) instead of the enhanced IBS data (the last row in Table 1) generates considerably different results. For instance, the government budget balance variable becomes insignificant. More importantly, the interaction term between the United States and the USD share variable becomes insignificant. Thus, a researcher using the consolidated data instead of the enhanced IBS data would not have been able to properly identify to the role of the US dollar currency network in driving safe haven flows to the United States.

Lending to banks versus non-banks

In order to better understand of the underlying mechanisms driving the above results, we examine the behaviour of the two main cross-border bank lending recipient sectors: banks (including related offices) and non-banks separately. 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[17] 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 $S=\{B;NB\}$.

We estimate equations (2) and (3) separately, as in many studies in the existing literature (Table 6). We find that the coefficient estimates for lending to banks are qualitatively similar to those from the benchmark regression (first column). 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 (second column). Most importantly, 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). In addition, 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 Appendix B).

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$_l$)*	–0.345	–3.90	0.0001	–3.43	–0.338	0.0008
Lending banking system deposit growth (*DepositGrowth$_l$*)	0.401	2.97	0.0030	0.10	0.007	0.9413
Borrowing country budget balance *(BudgetBalance$_b$)*	0.414	4.36	0.0000	–0.12	–0.011	0.9150
US borrower – USD share interaction *(US$_b$*USDShare$_{b,l}$)*	0.098	8.16	0.0000	0.04	0.043	0.6681
EME borrower – USD share interaction *(EME$_b$*USDShare$_{b,l}$)*	–0.101	–4.4	0.0000	–0.25	–0.115	0.2493
R-squared (in %)	8.62			3.13		
Number of observations	1067			1164		

[1] All coefficient estimates are multiplied by 100 to ease representation.

Source: Authors' calculations.

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. The most likely explanation of this pattern is related to the interaction between the international risk-taking channel of monetary policy (Rey (2015)) and the core-periphery network structure of the modern global banking system (Bruno and

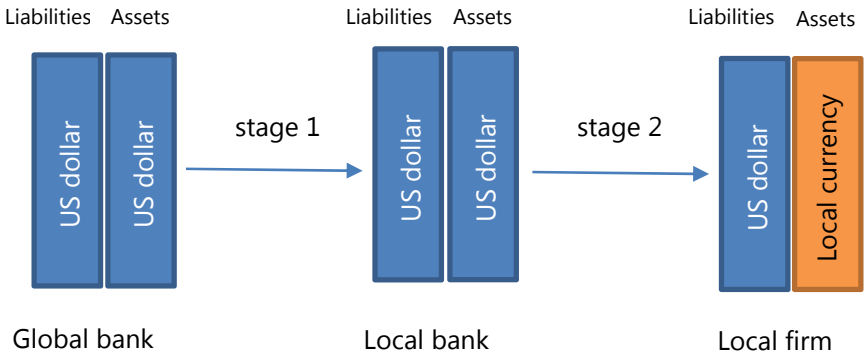
[17] Just as in the benchmark equation, we weigh each observation in the two sector-specific equations by the share of cross-border claims that lending banking system *l* had on the respective (bank or non-bank) sector in borrowing EME *b* in total cross-border bank lending (across all borrower-lender 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.

Shin (2015a)). We build a stylised model to formalise the above mechanism in the next section.

6. A stylised model of US dollar-denominated bank lending

To formalise the intuition behind our empirical findings, we build a model (inspired by Bruno and Shin (2015a)), in which regional banks borrow in U.S. dollars from global banks to lend further to local firms. We focus on one key aspect - the impact of currency fluctuations on international bank lending. In this stylized model, a dollar appreciation reduces the net worth of a firm with US dollar liabilities and local currency assets. This reduces the available collateral, thereby lowering lending from the local bank to the firm – which in turn lowers the local bank's demand for credit from the global bank. In short, the model illustrates how fluctuations in the value of the US dollar can affect even the activity of banks which have no currency mismatches on their balance sheets, but whose borrowers are exposed to exchange rate risk.

As illustrated below, the model uses a stylized lending relationship between a global bank and a local bank (stage 1) and between the local bank and a local firm (stage 2). The global bank lends in dollars to the local bank, which in turn also lends in dollars to the local firm which invests in the local economy, ie in local currency. All actors are risk neutral profit maximizers.



There are six periods in the model:

1) At time 1, the local bank lends *L* US dollars to the local firm (stage 2), and the firm invests the loan proceeds in a local project, yielding gross returns *R* at time 2 in local currency. There is no return uncertainty in local currency. The exchange rate at period 1 is normalised to *1*. The local firm has capital K, which it pledges as collateral behind the loan. The local bank charges an endogenously determined interest rate *r* for the loan, which is set in equilibrium at breakeven levels. Bankruptcy is costly, so if the firm is unable to repay the loan, only a fraction δ ($0<\delta<1$) of the remaining assets are transferred to the local bank.

   The local bank finances this lending by borrowing from the global bank (stage 1). For the sake of analytic tractability we assume that the local bank has enough capital to repay the global bank under all scenarios. The risk free rate is normalised to zero.

2) At time 2, uncertainty about the US dollar exchange rate is resolved: with probability θ ($0<\theta<1$), the US dollar appreciates (X=E<1) and with probability 1-θ it depreciates (X=1/E>1). With a weak US dollar, the returns from the project are sufficient to repay the loan but not with the strong US dollar. Formally:

$$L < R/E \qquad\qquad L > R^*E$$

We assume that the firm has enough capital to repay the local bank even with the strong USD, ie $L < K+R^*E$.

We further assume that, even with the exchange rate uncertainty, the project has a positive expected NPV in dollar terms *under the zero risk-free rate*, ie

$$\theta RE + (1-\theta)R/E \geq 0 \qquad \text{(M1)}$$

3) At time 3, the firm repays the local bank (stage 2), and the local bank repays the global bank (stage 1).

4) At time 4, the firm and the banks face the same problem (as at time 1), with two modifications. First, the starting exchange rate is E (if the dollar had appreciated at time 2) or 1/E (if the dollar had depreciated at time 2). Hence, the dollar loan to finance the project is L^*E or L/E – but the project still has a gross return rate of R in local currency, ie the return is either R^*L^*E or R^*L/E.

Second, the available capital of the firm depends on the previous realisation of the USD exchange rate. The remaining capital is equal to the original capital plus the proceeds of the project less the cost of financing, ie in case of strong dollar: $K'=K+R^*E-L$ and in case of weak dollar: $K''=K+R/E-L$

5) At time 5, the exchange rate uncertainty is resolved again with the same probabilities as in time 2. The dollar can appreciate or depreciate from its period 2 exchange rate. If the dollar was weak in period 2, then after strengthening its exchange rate becomes X=1 and after weakening X=1/(E^2). Conversely, if the dollar was strong, in period 2, then its exchange rate becomes either E^2 (if the dollar appreciates) or 1 (if it depreciates).

6) The firm repays the loan in full or goes bankrupt. The local bank repays the global bank.

Note that the global bank always finances the local bank at the zero risk-free rate (since the local bank is solvent in all states of the world). Furthermore, there is no risk for period 1 lending, so the local bank lends at zero interest rate. We also know, because of condition (1), that the firm always undertakes the project if it can be financed at the risk-free (zero) interest rate.

Hence, the only question is whether the local bank will finance the local firm at time 4. There are three scenarios:

Scenario 1: If at time 2 the US dollar exchange rate was weak, then the bank can finance the new project at the risk free interest rate (normalised to zero), because the firm has enough capital to repay the loan even under strong dollar.

Scenario 2: If at time 2 the US dollar exchange rate was strong, but the firm has enough capital to repay the bank in the case of further dollar appreciation, then the local bank can still finance the project at the risk free rate. Formally, this is the case if:

$$K' \geq LE - RE^2,$$

which can be expressed in terms of starting firm capital as:

$$K \geq L - RE + LE - RE^2 \quad \text{(M2)}$$

Scenario 3: The interesting case is when at time 2 the dollar appreciated and the firm's capital is not sufficient to withstand another dollar appreciation, ie condition (M2) is not satisfied.

The problem is that now the loan to the local firm is risky: if the dollar appreciates again then the firm cannot repay the local bank and goes bankrupt. In principle, the local bank can charge high enough interest rates to compensate for the losses it suffers in the strong dollar case. Formally, the interest rate necessary to provide the loan at breakeven profit is:

$$\theta\delta[RE^2 - LE + K'] + (1-\theta)[LE(1+r)] = LE,$$

The first term on the left-hand side shows the local bank's payoff if the dollar appreciates further (and the firm goes bankrupt) while the second term represents the respective payoff if the dollar depreciates. The expression can be simplified to:

$$1 + r = \frac{EL - \theta\delta[RE^2 - LE + K']}{(1-\theta)EL} \quad \text{(M3)}$$

Where, as defined above:

$$K' = K + RE - L$$

But this risky interest rate is only feasible if (i) the project can generate enough returns under a weak dollar in period 5 to pay the break-even interest rate in (3) and (ii) the project remains profitable for the firm in expected terms. Trivially, condition (ii) implies condition (i), because if undertaking the project is profitable then the firm cannot go bankrupt under a weak dollar. Hence, lending is feasible if the gains from undertaking the projects in the weak dollar case (left-hand side of (M4)) yield higher profits than not undertaking it (right-hand side of (M4)):

$$(1-\theta)[R - LE(1+r) + K'] \geq K' \quad \text{(M4)}$$

which implies that the set of possible interest rates is bounded by above:

$$\frac{(1-\theta)R - \theta K'}{LE(1-\theta)} \geq (1+r) \quad \text{(M5)}$$

In sum, lending can only take place in scenario 3, if the interest rate implied by M3 (the bank's zero profit condition) is consistent with M5 (the firm's participation constraint (case A). Otherwise, lending does not take place (case B).

In sum, lending takes place in all scenarios at time 1. At time 4, the project is not undertaken and lending does not take place if the balance sheet of the firm was sufficiently weakened by the time 2 exchange rate shock (Scenario 3 – case A).

The above stylised model shows that, even though formally both the global and the local bank have no currency mismatches on their respective balance sheets, their activity still depends on the US dollar exchange rate. In particular, a strengthening of the US dollar weakens the balance sheet of the ultimate borrower (ie the local firm). And, if the borrowing firm's balance sheet is not strong enough, a negative exchange rate shock could cause a reduction in lending from the local bank. This would in turn decrease the local bank's demand for cross-border interbank funding from the global bank. Therefore, the model predicts that an event such as the 2013 taper tantrum would cause cross-border interbank claims to decline by more for "core-periphery"

interbank lending pairs which rely more on US dollar lending. As discussed above, this is exactly what our empirical findings suggest.

7. Conclusion

Our paper contributes to the rapidly growing literature on cross-border monetary policy spillovers by examining the importance of currency networks in cross-border bank lending. More concretely, we undertake two main tasks.

First, we utilise the recently enhanced BIS international banking statistics, which simultaneously provide information on the lender, borrower and currency composition of cross-border bank claims to map 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. Our mapping also suggests that the borrowing country matters more for the currency composition of cross-border claims than the lending banking system. In other words, the destination is more important for currency denomination than the source.

Second, we demonstrate that currency networks in cross-border bank lending have a significant impact on the size, distribution and direction of cross-border monetary policy spillovers. Our analysis of the 2013 Fed 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 during that episode. 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. Our analysis also reveals that this pattern is primarily shaped by interbank lending. By contrast, lending to non-banks is not affected by the currency denomination of claims in a statistically significant manner. Finally, we also present a stylised model (inspired by Bruno and Shin (2015a)), which formalises the intuition behind our main results.

The above findings have implications for the assessment of financial vulnerabilities. Namely, the results suggest that, when it comes to cross-border bank lending, it is not only the nationality of the lending bank which counts: the currency composition of claims also matters for the transmission of external shocks. For instance, more US dollar denominated lending from UK banks to emerging market banks was associated with lower lending during the taper tantrum. Therefore, policymakers in emerging markets may want to monitor not only the quantity and sources of cross-border loans, but also the currency in which loans are denominated. Exposure to dollar loans implies different response to shocks than, say, exposure to euro loans.

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 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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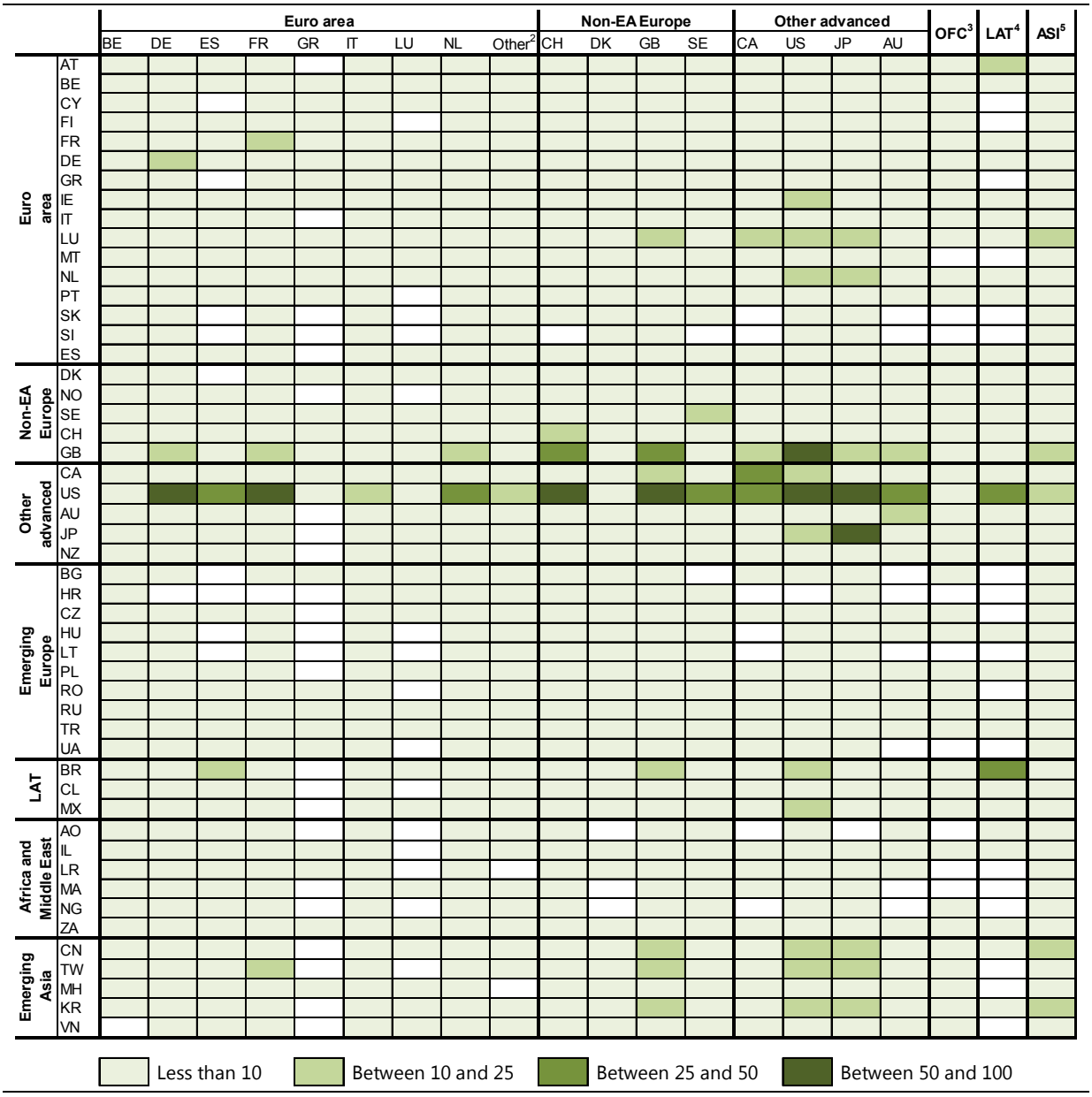
Appendix A: Currency network intensity heat maps

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.

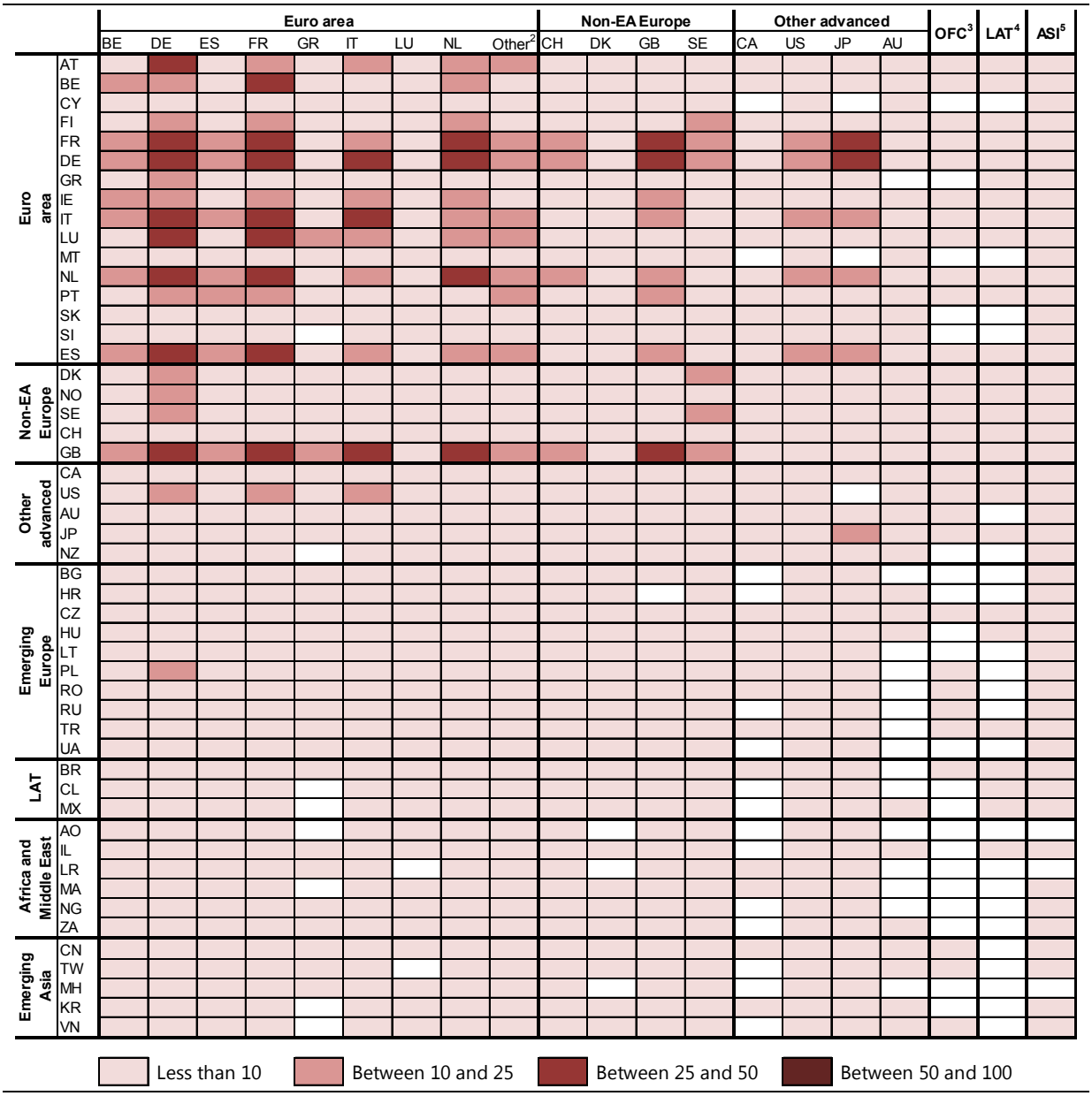
AO = Angola; AT = Austria; AU = Australia; BE = Belgium; BG = Bulgaria; BR = Brazil; CA = Canada; CH = Switzerland; CL = Chile; CN = China; CY = Cyprus; CZ = Czech Republic; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; FR = France; GB = United Kingdom; GR = Greece; HR = Croatia; HU = Hungary; 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 enhanced 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.

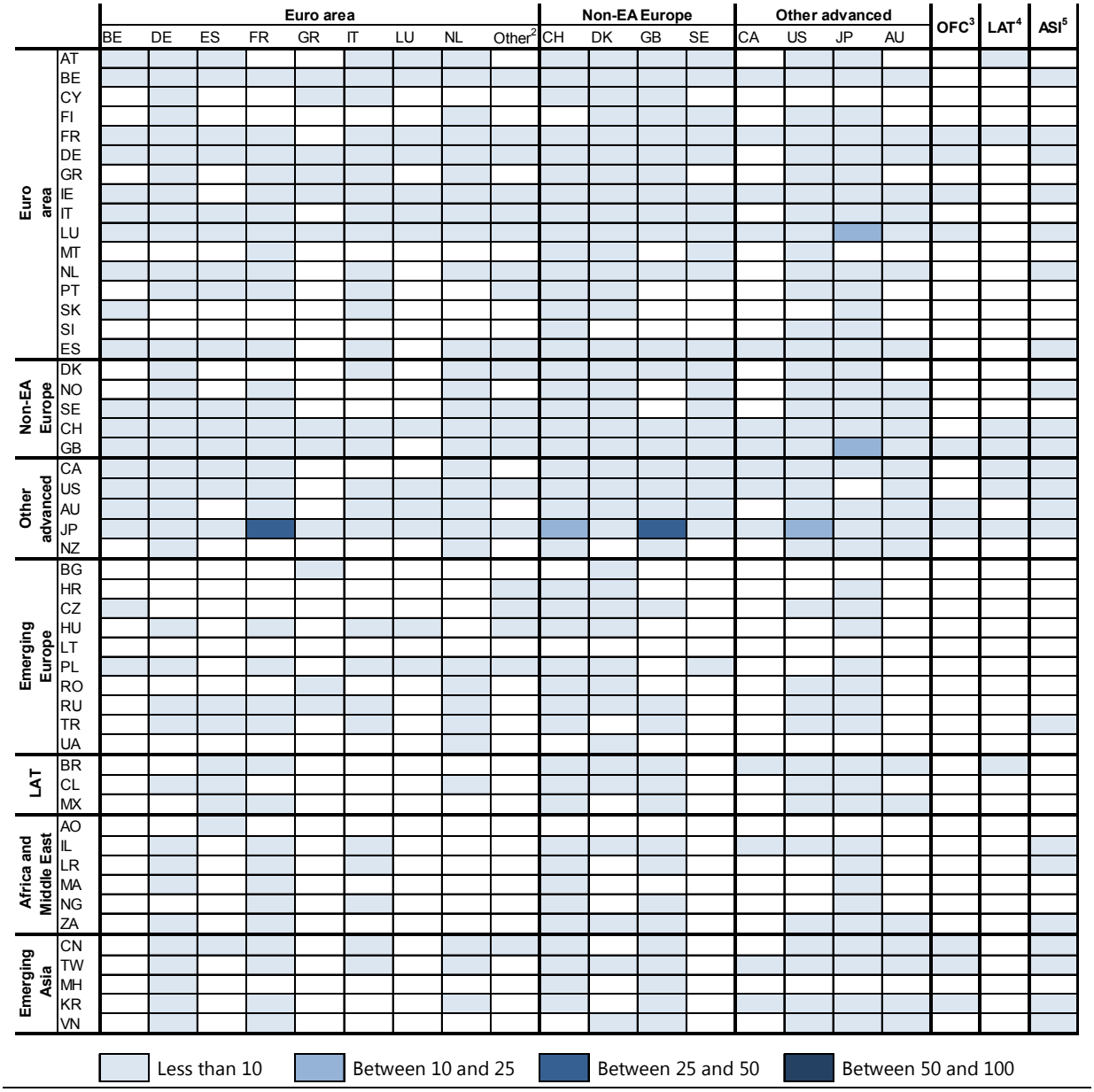
AO = Angola; AT = Austria; AU = Australia; BE = Belgium; BG = Bulgaria; BR = Brazil; CA = Canada; CH = Switzerland; CL = Chile; CN = China; CY = Cyprus; CZ = Czech Republic; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; FR = France; GB = United Kingdom; GR = Greece; HR = Croatia; HU = Hungary; 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 enhanced 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 enhanced 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 differences between 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 significant.

Based on the Wald test results, we estimate equations (2) and (3) as a system in the following fashion. 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.

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