Macroprudential policy cross-border spillovers and international banking - Any use for the gravity model?

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Abstract

In this paper I study whether the effects macroprudential policy leak cross borders through international banking. I combine data on bilateral bank asset holdings between 117 countries with a recently compiled dataset on the use of macroprudential tools. I consider a gravity equation of trade in financial assets, where the use of different macroprudential tools enter as friction variables. My preliminary findings support the gravity approach and the existence of spillovers from macroprudential policies.

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1 Introduction

The proliferation of the use of macroprudential instruments after the financial crisis has been rapid and widespread. Macroprudential policy as a distinctive framework of economic policy is such a recent development that research on macroprudential policy is still limited relative to the study of other policy frameworks. Even though the field has expanded rapidly, there remains substantial gaps in knowledge about the use of macroprudential tools, their effectiveness and transmission mechanisms. To gain fuller understanding on the effectiveness of macroprudential policies, one should not confine considerations to the ability of prudential tools to deliver the desired outcomes inside the country implementing the policies. After all, macroprudential policy cannot be implemented in a hermetic bubble, and thus some leakages and spillovers from the use of macroprudential instruments are unavoidable.

There is growing evidence that the effects of macroprudential instruments occasionally spill over borders through international bank lending (see e.g. a meta study of Buch and Goldberg and the research cited therein, 2016, Agénor et al., 2017) and that this may reduce the effectiveness of national macroprudential policies (e.g. Reinhardt and Sowerbutts, 2015). In the presence of large, free and fast-moving capital flows and extensive cross-border activities of large international banks, the effects of macroprudential policies are not confined in the country that implements them. Cross-border spillovers of macroprudential policy may arise e.g. when banks exploit differences in the standards of national regulation by placing their activities in countries with the least imposing regulatory requirements. This regulatory arbitrage can to some extent be mitigated by mutual recognition, often referred to as reciprocity, of macroprudential measures by the national authorities of different countries[1]. Even though the leakages have so far been found to be rather small, they may increase as national macroprudential policies become more widespread (Buch and Goldberg, 2016). My preliminary result support the notion that the effects

[1]See e.g. Agénor et al. (2017), Chen and Phelan (2017), and Engel (2015).

of macroprudential tools leak across borders through international lending.

Multi-country empirical research on the effectiveness of macroprudential policy has been limited by the lack of data. This has been due to the fact that the formal macroprudential framework is still in many ways taking shape and that instead of a single widely used policy instrument such as the policy rate in monetary policy, there are a multitude of different macroprudential tools, each implemented with differences in scope, intensity and details by different countries. A recently published data set compiled by the IMF (described in Cerrutti et al., 2017) is the first attempt to stand up to the task of documenting the use of these tools across a large set of countries. The data provides the most extensive database to date on the use of macroprudential policies by documenting the use of various macroprudential policies in a sample of 119 countries over the years 2000-2013. This data comes from the Global Macroprudential Policy Instruments (GMPI) survey carried out by the IMF during 2013-2014. Cerrutti et al. (2017) use the data to conclude that usage of macroprudential policies is generally associated with lower credit growth and greater cross-border borrowing.

The GMPI data could potentially be used in a myriad of setups, as pointed out by Cerrutti et al. (2017). I combine the data on the use of prudential tools with a network of bilateral banks asset holdings, which I build using the locational banking statistics compiled by the Bank of International Settlements (BIS). To my knowledge, my paper is the first one to consider these data together. My goal is then to find out whether the gravity model of cross-border trade in financial assets[2] can give some insight on cross-border spillover-effects of macroprudential tools on bank asset holdings. Specifically, I consider whether after taking into account the usual frictional variables of the gravity set-up, the use of prudential tools will have an effect on bilateral cross-border banking asset holdings. I am aware of only one paper, <Houston et al. (2012), that explicitly considers the effects of regulation on international

[2]As first proposed by Portes and Rey, 2005, and the basis of a fast-expanding strand of literature. See Head and Mayer, 2014, for a thorough survey.

bank activity in the gravity framework, but with different data. In addition to estimating my gravity equations using the more common approaches[3], I use a two-stage approach, that allows for considering the potentially different effects of prudential tools on the intensive and extensive margins of banks extending loans to foreign borrowers. The double-hurdle methodology has not been considered before in the context of gravity in international banking.

The rest of the paper is organized as follows. The related literature is reviewed by strands in section 2. My research questions, hypothesis and model are formulated and discussed in section 3. In section 4 the data are presented and in section 5 the methodology chosen. The empirical results are presented in section 6. Section 7 concludes.

[3]<The probit+OLS, the PPML (Interpretation?)

2 Related literature

This paper is related to multiple strands of literature. First, my paper is related to the broad field on the effects of macroprudential policy. More specifically, I contribute to the literature on the cross-border effects of macroprudential policy, or regulatory spillovers and leakages associated with macroprudential policy tools. Second, my results also add to the knowledge on what affects international banking flows by providing an application of the gravity model for bilateral cross-border bank holdings.

2.1 On the effects of macroprudential policy

As the active use of macroprudential framework in the sense it is currently understood in the advanced economies is quite a recent development, there are still large gaps in knowledge on the long-term macroeconomic effects and effectiveness of macroprudential policy. Because formal macroprudential policy frameworks have been put up en masse only after the global financial crisis, the discussion is still quite new and the definitions may not be well established. Also, there are not very long time series of data on the use of macroprudential policy, that would allow for definitive conclusions to be made on the framework's effectiveness, at least on the measures most used in advanced economies. In 2013 Galati and Moessner noted that research on macroprudential policy is "still in its infancy" and "far from being able to provide the analytical underpinning for policy frameworks". Even though the literature on macroprudential policy has expanded rapidly, much of the above is still accurate. The overall evidence on the effectiveness of macroprudential policies should still be considered preliminary, as pointed out by Cerrutti et al. (2017). The challenge is that there is not one primary instrument that would have risen from the broad range of possible macroprudential tools, taking a role comparable to the policy rate, which takes the primary role in the implementation of monetary policy. This makes the comparative assessment of macroprudential policies complicated. Further complicating the research, the differing objectives and

instruments of monetary, macroprudential, microprudential and fiscal policy are not clearly distinguishable but sometimes very closely interrelated (see e.g. Schoenmaker and Wierts, 2011).

Keeping these caveats in mind, there is however a growing body of evidence on the effectiveness of macroprudential policy. Cerrutti et al. (2017) find that macroprudential policies in general can have a significant effect on credit growth, but these effects are specific to both the instrument used and the country implementing the policy. They find that especially borrower-based and financial institutions-based policies appear to reduce credit growth. To motivate their theoretical model, Agénor et al. (2017) provide preliminary results which suggest that macroprudential tools have effects on macroprudential volatility. Fendoglu (2017) considers emerging economies and finds that an overall tightening in the macroprudential policy stance is effective in containing credit cycles. He credits borrower-based measures and stricter domestic reserve requirements to be the most effective tools. Dell'Ariccia et al. (2012) report results that show macroprudential policy reducing the probability of general credit booms and of those booms leading to serious financial instability. Claessens et al. (2013) consider the effects of different policies on the balance sheets of individual banks and find that while countercyclical capital buffers can help slow leverage growth in the banking sector, they may be of little use in times of financial downturns.

The history of financial crises makes it evident that financial instability has little respect for national borders (see e.g. Reinhart and Rogoff, 2009). The global financial crisis and the subsequent sovereign debt crisis experienced by the European Union showed that as the global financial markets have become ever more closely intertwined and economies ever more open, financial calamity can spread with a speed difficult to match by policy makers. This is one of the reason why academic research on the effects of macroprudential policy with at least some policy relevance mostly considers open economy settings. Many empirical papers focus on macroprudential policies in emerging economies, and consider cases when the economies are subject to large foreign capital flows.

Also papers focusing on advanced economies put emphasis on the open economy specifics of the problem (see e.g. Buch and Goldberg, 2016).

There is growing evidence that the effects of macroprudential instruments occasionally spill over borders through international bank lending (see e.g. a meta study of Buch and Goldberg and the research cited therein, 2016, Agénor et al., 2017) and that this may reduce the effectiveness of national macroprudential policies (e.g. Reinhardt and Sowerbutts, 2015). Using a dataset on prudential measures described in Cerrutti et al. (2017b)[4], Avdjiev et al. (2017) find evidence that the implementation of macroprudential measures has a significant impact on international bank lending that also results in cross-border spillovers. They find that most of the spillovers from tightening of macroprudential regulation lead to expansions in cross-border bank activity.

In the presence of large, free and fast-moving capital flows and extensive cross-border activities of large international banks, the effects of macroprudential policies are not confined in the country that implements them. Cross-border spillovers of macroprudential policy may arise e.g. when banks exploit differences in the standards of national regulation by placing their activities in countries with the least imposing regulatory requirements. This regulatory arbitrage can to some extent be mitigated by mutual recognition, often referred to as reciprocity, of macroprudential measures by the national authorities of different countries. Even though the leakages have so far been found to be rather small, they may increase as national macroprudential policies become more widespread (Buch and Goldberg, 2016).

The effectiveness of macroprudential instruments can be compromised if banks can take their lending activities outside the scope of the regulations or if domestic agents can borrow abroad. As Engel (2015) points out, if the domestic supervisor has different regulatory oversight on domestic banks and foreign branches or subsidiaries, macroprudential policy leakages and spillovers arise quite naturally. This has two consequences. First, the domestic economy remains exposed to systemic risk even after regulatory tightening. Second, the

[4]<Note that this is a different dataset than the one described in Cerrutti et al. (2017a).

domestic financial intermediaries are left at a disadvantage. This the motivation for reciprocity, i.e. mutual recognition of macroprudential measures by different countries.

However, reciprocity can also lead to the foreign financial institutions simply shifting their activities to other countries. In a sense, this can be a desirable outcome, insofar as it may reduce the fragility of the financial system and thus the risks to the domestic economy, but it can also have undesirable outcomes. First, this may lessen the options for domestic households and companies and it may also diminish the availability of expertise that may not be available locally and thus make also the domestic financial sector less competitive (Engel 2009). Most importantly, if regulation makes the foreign financial institutions to relocate, the possibly adverse effects of the resulting thinner financial markets may last a lot longer than the financial cycle. This why some economists, e.g. Korinek (2011) and Jeanne (2012), favor countercyclical capital controls instead of more stringent regulation. The problem of regulatory arbitrage would naturally disappear if regulation was completely harmonized across all countries. However, optimal macroprudential policy is highly unlikely to be identical across different economies, i.e. there is a trade-off between national customization and global harmonization of policy measures. This further adds to the need for understanding how the macroprudential policies affect cross-border banking. My contribution to this discussion is to provide a further approach, the gravity approach, for studying the spillover effects on bilateral cross-border banking. My findings lend support for there being cross-border spillovers from macroprudential policies and that the effects on bilateral cross-border lending may be fairly large.

2.2 International banking and the gravity model

The gravity model has been a workhorse of international trade literature for decades[5]. As the name suggests, the model, originally borrowed from physics,

[5]See e.g. Anderson (1979) for an early formulation and Head and Mayer (2013) and Anderson (2010) for surveys.

explains a flow between two entities by simply relating it to their two masses and a friction term. The classic gravity result states that as the distance between two entities increases, the bilateral trade between them decreases. The simplest version of the log-linearized model requires only the economic masses of the domestic country and the foreign country, such as GDPs, and the distance of the two countries as an approximation for transaction costs:

$$trade_{ij} = \beta_1 GDP_i + \beta_2 GDP_j + \beta_3 dist_{ij}, \tag{1}$$

where $trade_{ij}$ denotes the trade flow to country i from country j, GDP_i and GDP_j are the gross domestic products of countries i and j respectively and $dist_{ij}$ denotes the distance of the two countries. (Portes and Rey, 2005) In more elaborate versions the number of variables increases, but in general, in a gravity specification bilateral trade is a product of measures of economic size, a bilateral barrier (such as distance and other trade frictions) and multilateral resistance term (Anderson and van Wincoop, 2004). Portes and Rey (1998) were one of the first to propose that a gravity equation could also explain bilateral financial asset flows, finding that the model fit the data on bilateral cross-border investments surprisingly well.

The gravity model of international asset trade is currently one of the most widely used theoretical frameworks for studying the determinants of cross-border financial asset flows and holdings and understanding home bias[6]. The theoretical framework for a gravity model of cross-border asset flows derived by Martin and Rey (2004) and estimated by Portes and Rey (2005) is the most influential and widely estimated approach to gravity in international finance. This micro-founded two-country model with an endogenous number of financial assets relates the size of the two economies and trade costs to their bilateral asset transactions. The model also succeeds in providing an intuitively appealing explanation for home bias by assuming that transaction costs enter

[6]For other frameworks of studying home bias see e.g. Brennan and Cao, 1997, who study the differences in informational endowments of investors, and Couerdacier et al., 2010, who develop a RBC-model explaining home bias by capital accumulation and international asset trade.

the model non-linearly, enabling even small transaction costs to produce a high degree of home bias. The empirical model of Portes and Rey (2005) has been the basis of much of the study of determinants of cross-border portfolio investments. The gravity equation most often estimated in this context takes a form closely resembling something like this:

$$\begin{aligned} log(asset_{od,t}) =& \alpha_1 log(M_{o,t}) + \alpha_2 log(M_{d,t}) + \alpha_3 log(dist_{od}) \\ &+ \alpha_4 log(\text{information variables}) \\ &+ \alpha_5 log(\text{transaction technology variables}) \\ &+ \text{multilateral resistance} + \text{time dummies} \\ &+ \text{constant} + u_{od,t}, \qquad (2) \\ & o, d = 1, ..., N \text{ and } t = 1, ..., T, \end{aligned}$$

where $asset_{od,t}$ is the bilateral asset position, $M_{o,t}$ and $M_{d,t}$ capture the economic masses of the two countries and $dist_{od}$ refers to the distance between the capitals of the two countries. Theory predicts that the coefficients of the logs of economic masses are equal to one, and that distance has a negative effect on asset holdings. Thus it is expected that $\alpha_1 = 1$, $\alpha_2 = 1$, $\alpha_3 < 0$. It is common to include different variables to capture some features of information frictions or transaction frictions between the two countries, such as whether they share a common border, a language or a currency. Time dummies capture the effect of macroeconomic disturbances and regional dummies the effect of the multilateral resistance term (see e.g. Coeurdacier and Martin, 2009).

The gravity model was taken up quickly in the study of financial asset trade and as IMF began publishing data on bilateral portfolio investment asset holdings [7], papers making use the approach proliferated. Most of the papers[8] confirm the classic gravity result, i.e. that as distance increases, bilateral tradein financial assets decreases. The "distance puzzle" is then just another name for the classic home bias puzzle.

The gravity model has since been applied to studying the determinants of

[7] The Coordinated Portfolio Investment Survey, or CPIS-database is available at <

[8] <Add list of refs

foreign direct investments, M&A's and also international banking. Already in 2005 Buch published a paper considering the gravity approach to international banking, and the most recent example of an application to cross-border banking is a recent paper by Brei and von Peter. These papers broadly confirm the classic gravity result to apply also to international banking, i.e. that bilateral bank asset holdings decrease as the distance between the origin and destination countries increase.

<Houston et al. (2012): Regulatory arbitrage and international bank flows

3 Data

This section describes the data used in my analysis. For the purpose of the gravity model, all data is considered in a bilateral framework with multiple countries of origin and destination countries. Here a *country of origin* refers to the country where the bank operates as a bank with a domestic headquarter or a subsidiary of a bank with a foreign headquarter. The *destination country* is the country to which the banks from the country of origin extend credit.

3.1 Data on the use of macroprudential tools

A major limitation to studying the effectiveness of macroprudential policies has been the lack of data. Among others, the International Monetary Fund has been active in trying to fill in this gap. Cerrutti et al. (2017a) make use of an IMF conducted Global Macroprudential Survey and previous studies to build a database that is the most ambitious take on the task to date.[9] The IMF has also initiated an annual survey on the use of macroprudential tools, results of which have been published twice.

The data compiled by Cerrutti et al. (2017a) is an annual index for 119 countries covering the period 2000-2013. To match the sample with the coverage of other data sources, I drop two countries from the sample and make do with 117 countries. The IMF survey covers all in all 18 macroprudential tools, but for this dataset 12 instruments are included. The instruments are divided into two categories following the classifications used by e.g. the IMF and European Systemic Risk Board and two aggregate indices are formed. First index comprises ten instruments that target financial institutions, referred to as $mpif$, the second two that are aimed at borrowers' leverage, referred to as $mpib$. *<Add a table with definition of the indices and the tools*

The indices are build in such a way that implementing any of the 10 or

[9]The Global Macroprudential Policy Instruments -, or GMP-data, has also been used in Cerrutti et al. (2017b). This data is for a smaller set countries, but it is quarterly and takes into account the intensity of the tool. *Should this data be used as robustness check for the subsample?*

2 tools results in an increase of the index by one integer. Thus if a country at a given year implements one more tool targeting financial institutions in addition to the one it already has, the value of the $mpif$ index becomes 2. The maximum value for $mpif$ is 10 and for $mpib$ 2.

Variable	Mean	Std. dev.	Min	Max	Range
$mpif$	1.38	1.24	0	6	0-10
$mpib$	0.36	0.66	0	2	0-2

Table 1: Macroprudential indices targeting financial institutions and borrowers

Value	0	1	2	3	4	5	6	7	8	9	10
$mpif$	28.9%	29.9%	23.8%	11.7%	3.7%	1.7%	0.4%	-	-	-	-
$mpib$	74.6%	15.3%	10.2%	-	-	-	-	-	-	-	-

Table 2: Use of macroprudential tools: % of all observations with n tools implemented

The most important thing to note and to keep in mind about the indices is that they simply document the number of macroprudential tools implemented by the countries during a given year. The intensity of the measures is ignored as well as changes in the stance of the different policies. That is, the index changes by the same amount for countries that implement a a 0.1 % countercyclical capital buffer and a country that implements a 5 % one. Also, the indices do not distinguish between a binding regulation and a recommendation. This allows for the broadest possible coverage of countries and instruments, but arguably gives a very simplified view of the policy field.

In other aspects also, the data is not without caveats. First of all the data is based on survey data, and thus all the usual challenges of survey data should be kept in mind. Second, the years covered coincide with a period during which the macroprudential framework was non-existent or just beginning to take shape. These facts considered together with the myriad of ways the details of the macroprudential tools vary across countries means that consistency is

most probably compromised. Still, the data provides a valuable stepping stone for research into the effects of macroprudential policies.

3.2 The dependent variable - bilateral bank asset holdings

The goal of this paper is to find out how the effects of macroprudential policies spill across borders to other countries. As the purpose of most macroprudential policies is to address excess growth of debt and leverage, it is natural to assume that the spillovers should affect lending also. Thus the dependent variable for the purpose of this paper is the bilateral cross-border bank asset holdings. The data comes from the BIS Locational Banking Statistics database, which provides the most extensive source of bilateral cross-border positions. This data is drawn from the balance sheets of banks that operate internationally and it allows for a geographical breakdown of their counterparties. <The counterparties can belong to any sector. This data is then aggregated to a country-to-country framework. In the full LBS dataset there are 44 reporting countries and 216 counterpart countries with quarterly observations from 1977 onwards. For the purpose of this paper I choose 33 of the reporting countries and 84 counterpart countries to match the countries for which I have data on the use of macroprudential tools.

To extend the coverage of the data on bilateral asset holdings, I overlay the data on assets held by origin countries in the destination countries onto data on liabilities of origin countries held by destination countries. This procedure, following Brei and von Peter (2018)[10], leads to a network of bilateral holdings for pairs of countries where both are BIS reporting countries or where either the origin country or the destination country is a BIS reporting country. Thus the observations that equal zero can be considered "true" zeros, as only observations for pairs where both countries are not BIS reporting countries are

[10] A detailed description of the procedure can be found in appendix A of Brei and von Peter (2018).

missing. This is noteworthy, as it affects the choice of estimation strategy.[11]

The dependent variable is thus bank asset holdings of banks in origin country that are the liabilities of borrowers in the destination country, denoted by ba_{od}, where o is the identifier of the origin country and d of the destination country. In Table 3 I report summary statistics for the whole sample and for the positive observations. There are 117 countries in the sample, of which 33 are BIS reporting countries and 84 are counterpart in the LBS data. After dropping some observations for which the data on controls is incomplete, 6112 country pairs enter the sample. The data are in millions of dollars, i.e. the mean of the positive observations is 11.3 billion dollars. Note that the position of banks in origin country vis-a-vis the destination country can be negative due to short selling. In the full sample there are eight negative observations of ba_{od}, but I have at least for the time being excluded them.

An important feature of the data is the share of zero observations. This share is very large; almost 45 % of all observed bilateral cross-border bank asset holdings equal to zero. This is a common feature in all bilateral data, be it data on international goods trade flows, cross-border portfolio asset holdings, foreign direct investments or banking data. That is, at any given time, a country trades with or invests in or extends credit to only a handful of other countries. The non-negligible share of zero observation calls for the use of estimation methods that are suitable for limited dependent variables. Failing to do so will inevitably result in biased estimates. A common, simplified approach is to drop the zero observations and simply estimate the effects in the positive part of the sample, but this risks biased results also. Surely there is a reason for the share of zero observations, be it barriers to trade, prohibitively large trading costs or something else, and ignoring this will result in an over-simplified picture of what drives bilateral trade or investment flows.

[11] Side note: the publicly available locational banking statistics is not very useful because so much of these bilateral observations are confidential. I however have all the data, as I had access to it when I was at the Bank of Finland, so confidentiality is not an issue here.

	ba_{od}	$ba_{od} > 0$	$log(ba_{od} + 1)$	$log(ba_{od})$
N of pairs	6 112	4 674	6 112	4 674
N of periods	14	14	14	14
N of observations	85 560	51 013	85 560	51 013
Mean	6 277.04	11 281.03	2.95	5.19
Standard deviation	56 285.91	75 081.81	3.43	3.12
Min	0	0.01	0	-4.61
Max	2 962 748.00	2 962 748.00	14.90	14.90
Share of 0s	44.35 %	-	44.35 %	-

Mean, standard deviations, min and max in millions of US dollars.

Table 3: Summary statistics of the dependent variable.

3.3 The other controls

For the gravity model two types of independent variables are required. One should have some variables that account for the economic masses of the two countries, such as the GDP, GDP per capita or market capitalization. In addition to these there should be different variables that account for the frictions of trade (in goods or in financial assets) between the two countries. Usually distance is included, but the other frictions can be a myriad of things. Note also that some of these variables can be also factors that facilitate trade between the two countries by, say, increasing the flow of information between them.

For the purpose of this paper, I use annual GDP for a measure of the economic masses of both the origin country and the destination country.[12] The GDP data is annual data in dollars from the World Bank.

Distance is measured as population-weighted distance between the largest cities of the two countries. The data for distance comes from the gravity database of CEPII, as does data for four of the most common gravity dummies:

[12]One possible modification/robustness check: use the size of the banking sector for the country of origin, as supply of finance can be thought to depend on the size of the financial sector, and GDP for the destination country, as the demand for finance should depend on the size of the economy.

contiguity, common language, common colonial history and common currency. They are all expected to reflect less frictions in bilateral trade. There is an almost countless number of other possible controls one could use, but these are the most commonly used and the ones most often found to have a statistically significant effect on bilateral asset holdings.

In addition to the usual gravity controls, I control for financial sophistication by using an indicator for income group and dummies for financial openness, membership of the WTO and of the EU. The indicator for income group is obtained from the IMF World Economic Outlook. There are 23 advanced, 63 emerging and 31 developing countries in my sample, but in the observations the share of advanced economies is much higher than a quarter. This is because advanced economies are also BIS reporting countries, thus oservations where at least one of the pair is an advanced economy is highly unlikely to be missing. On the other hand none of the BIS reporting countries is a developing country. Thus observations where one of the countries is a developing country are much more likely to be missing. The dummy for financial openness is from Cerrutti et al. (2017, updating Lane and Milesi-Ferretti, 2007), and it takes value 1, if a country is considered financially open by this measure[13]. 48 of the countries in my sample are considered financially open using this measure. The dummies for membership in the WTO and the EU are both from the CEPII's gravity database.

In the gravity literature, the need to control for a so called multilateral resistance term is emphasized. This is meant to capture the fact that the assets of any given country must "compete" with the assets of all the other countries. This term is often proxied by regional dummies, which is the approach I have taken. They could also be proxied by country fixed effects on the pairs, or all the origin countries and the destination countries. In this case most the gravity controls would not be needed, because they would be captured by the

[13]A country is classified as financially open if its median openness score over 2000-2011 is greater than the median score for all countries in the sample. Otherwise it is categorized as financially closed.

country fixed effects.

In the equation to be estimated the continuous variables, i.e. the dependent variable, the economic masses and distance will be in logs, because here the nature of the relationship between the dependent and the independent variables is such that a percent change in an independent variable causes a percent change in the dependent variable. With the other controls the relationship is such that a unit change causes a percent change in the dependent variable. Thus the other controls are in integers or dichotomous. This means that the equation to be estimated will be a combination of a log-log and a log-lin equation.

The summary statistics for the continuous independent variables are documented in Table 4 and for the dichotomous controls in Table 5. The variable denoting the income group of the countries takes value 0 for developing countries, 1 for emerging economies and 2 for advanced economies. The dummy indicating whether an economy is considered financially open or closed takes value 1 for financially open economy and value 0 for financially closed economy. The

Variable	Mean	Std. dev.	Min	Max	Obs.
$log(gdp_o)$	25.47	1.28	20.78	25.98	85 560
$log(gdp_d)$	23.19	2.68	12.07	30.17	85 560
$log(distw_{od})$	8.58	0.81	4.39	9.76	85 560

Table 4: Continuous independent variables

Value of variable	0	1	2	Obs.
incomegr	11.52 %	43.81 %	44.67 %	85 560
$finopen$	44.37 %	55.63 %	-	85 560
contig	98.23 %	1.77 %	-	85 560
comlangof	88.15 %	11.85 %	-	85 560
*col*45	98.49 %	1.51 %	-	85 560
comcur	96.63 %	3.37 %	-	85 560
wto	8.62 %	91.38 %	-	85 560
eu	70.63 %	29.37 %	-	85 560

Table 5: Dichotomous controls: %-share of observations

4 The model

4.1 Research questions

The goal of this paper is to find out whether the gravity approach could be useful in the study of cross-border spillovers of macroprudential policies and how these spillovers are transmitted through international lending. To this end I formulate two research questions.

- Can the gravity model tell us something about the cross-border spillovers of macroprudential regulation through international lending?
- Does the implementation of macroprudential instruments in the origin country or the destination country have an effect on the bilateral cross-border bank asset holdings?

The first of the questions is more general in nature: I am interested in simply finding out wheter after controlling for the usual gravity variables, the inclusion of variables measuring the use of macroprudential instruments plays any role in the gravity framework. The second question is more specific and focuses on the effect of macroprudential regulation on bilateral cross-border bank asset holdings.

To answer these questions, I specify a gravity equation with four independent variables controlling for the use of two classes of macroprudential tools in the origin country and the destination country as Equation 4. The dependent variable is the log of bilateral bank assets, held by banks in origin country with destination country as the counterpart. The economic masses of the origin and destination countries are represented by annual GDP in logs. The population-weighted distance between the two countries is also in logs.

The variables measuring the use of macroprudential regulation in the origin and the destination country can be seen on the second row of Equation 4. The value of the index for macroprudential tools targeted at financial institutions in the destination and origin country are given by $mpif_{d,t}$ and $mpif_{o,t}$ respectfully. The value of the index for macroprudential tools targeted at borrowers in the destination and origin country are given by $mpib_{d,t}$ and $mpib_{o,t}$ respectfully.

I include the four most common gravity controls (dummies for contiguity, common official language, common colonial history and common currency) and four variables that are often assumed to account for financial sophistication (income group, financial openness, membership of the WTO and the EU). I proxy multilateral resistance by using regional dummies, and include time dummies to account for macroeconomic conditions. There are 117 countries that can both be origin or destination countries. After discarding missing values, i.e. the observations where neither of the countries is a BIS reporting country, the sample consists of 6112 country pairs. Time runs from 1 to 14, i.e. from 2000 to 2013.

Thus the gravity equation of cross-border bank asset holdings for the pur-

pose of this paper is given by Equation 4:

$$\begin{aligned} log(ba_{od,t}) =& \alpha_1 log(GDP_{o,t}) + \alpha_2 log(GDP_{d,t}) + \alpha_3 log(distw_{od}) \\ &+ \alpha_4 mpif_{d,t} + \alpha_5 mpif_{o,t} + \alpha_6 mpib_{d,t} + \alpha_7 mpib_{o,t} \\ &+ \text{gravity controls} \\ &+ \text{controls for financial sophistication} \\ &+ \text{multilateral resistance} \\ &+ \text{time dummies} \\ &+ \text{constant} + u_{od,t}, \qquad (3) \\ & o, d = 1, ..., 117 \text{ and } t = 1, ..., 14. \end{aligned}$$

4.2 Hypotheses on the effect of macroprudential tools on bilateral bank asset holdings

In this section I formulate the ex-ante hypotheses of how one should expect the use of macroprudential regulation to affect the bilateral bank asset holdings.

One might think that banks should simply be expected to move into markets with less regulation and out of markets with more regulation, and thus the effect macroprudential regulation to always induce banks to reduce cross-border holdings in the country implementing regulations. This is however a too simplistic look at macroprudential regulation. As mentioned before, the lack of a one definitive macroprudential tool means that there are in fact a multitude of different tools with different targets. The motivation behind using two indices of macroprudential tools is just this: even though macroprudential tools that are aimed at different actors on the financial markets may all work towards a common goal of moderating credit growth, they work through different transmission channels and thus their potential spillovers are also different.

I formulate my hypotheses in the spirit of Reinhardt and Sowerbutts (2015) and separate between the effects of regulation that is aimed at financial institutions and that is aimed at borrowers. A crucial assumption behind the distinction is that the scope of these type of regulations often differs. Regulation that

targets financial institutions is assumed to apply only to domestic banks, i.e. banks with a domestic headquarter and subsidiaries of foreign banks. These are the banks that are usually under domestic financial supervision. Foreign banks that operate via branches usually are not. On the other hand, regulation that targets borrowers is usually applied to all domestic borrowers, thus affecting also foreign banks via their domestic customers.[14] The hypotheses are formulated as follows:

Hypothesis 1. *Implementing macroprudential regulation aimed at domestic financial institutions leads to domestic agents borrowing more abroad.*

Hypothesis 2. *Implementing macroprudential regulation aimed at domestic borrowers does not lead to more borrowing from abroad, but instead domestic banks might move lending to less regulated markets.*

The Hypothesis 1 states that regulation, that is aimed at financial institutions, such as tightening capital requirements, is expected to lead to domestic agents borrowing more from abroad. This happens because as capital requirements increase, the weighted average cost of capital for banks subject to this measure increases. As noted above, macroprudential regulation applies to banks that are under domestic supervision. Thus a funding advantage for foreign banks is created and borrowing from abroad should thus increase.

The Hypothesis 2 states that macroprudential regulation, that targets domestic borrowers, such as caps on loan-to-value- and debt-to-income-ratios, should not have the similar effect as regulation aimed at financial institutions. This is because now there is no funding advantage for foreign banks: these macroprudential tools apply to also foreign banks via the domestic customers. Thus increased lending abroad should not be the result. Instead, the regulation might affect cross-border banking if it will lead to banks moving lending to less heavily regulated markets.

To fit these hypotheses into the bilateral gravity framework, I specify the hypotheses further in a more detailed manner. This requires differentiating

[14]Note: There are several arguments for why this assumption may be too simplistic.

between the effects of macroprudential regulation implemented in the origin country and in the destination country. These will have an effect of opposite signs on the bilateral bank asset holdings. The first two of these more detailed hypotheses, Hypothesis 3 and Hypothesis 4, concern the effect of macroprudential regulation aimed at financial institutions.

Hypothesis 3. *Implementing macroprudential regulation aimed at domestic financial institutions in the destination country leads to higher banking flows from O to D as banks from the origin country take advantage of a funding differential: a higher* $mpif_d$ *is associated with a higher* ba_{od}*.*

Tighter regulation in the destination country leads to higher banking flows from the origin to the destination as banks from the origin country take advantage of the funding differential. Thus a higher $mpif_d$ index for destination country is expected to be associated with more cross-border lending.

Hypothesis 4. *Implementing macroprudential regulation aimed at domestic financial institutions in the origin country leads to lower banking flows from O to D as banks from the origin country face more stringent regulation and increased competition: a higher* $mpif_o$ *is associated with a lower* ba_{od}*.*

On the other hand, tighter regulation in the origin country creates a funding advantage for foreign banks, increasing competition in the domestic market. This may lead to lower banking flows from origin country to destination country if banks from the origin reduce cross-border activity to better comply with regulation and to take on increased competition. Thus a higher $mpif_o$ index for origin country is expected to be associated with less cross-border lending.

The regulation aimed at domestic borrowers works differently, because it applies to domestic agents and via them to all banks operating in the domestic market. Now there is no funding advantage for domestic or foreign banks, and there is no effect on international lending through this channel. However, tighter regulation can still spill over, if banks retreat from a more regulated market to a less regulated one.

Hypothesis 5. *Implementing macroprudential regulation aimed at domestic borrowers in the destination country leads to lower banking flows from O to D as banks from the origin country retreat from a more heavily regulated market: a higher* $mpib_d$ *is associated with a lower* ba_{od}*.*

Hypothesis 6. *Implementing macroprudential regulation aimed at domestic borrowers in the origin country leads to higher banking flows from O to D as banks from the origin country move lending to less heavily regulated markets: a higher* $mpib_o$ *is associated with a higher* ba_{od}*.*

That is, in the case of implementation of macroprudential regulation aimed at borrowers, the internationally active banks have an incentive to shift lending towards a market less heavily regulated.

<Side note: these hypotheses are not consistently confirmed in the estimations. This may be because of the different uncertainties and peculiarities of the data, the highly non-linear model or then the channels of effect are somehow different. This is something I clearly need to figure out.

5 Estimations

In this section I go through the possible and chosen estimation methods and present the preliminary results.

5.1 Estimation methods

There are a number of different estimation methods that are used to estimate the gravity equation. The most simple one has also been the most commonly used: a panel fixed effects OLS with zero observations excluded. This approach, which following Portes and Rey (2005) taken by most of the studies considering the gravity model of financial asset trade fails to address the clustering of zero observations. As with most bilateral data however, the share of zero-observations is non-negligible and thus these observations need to be taken into account to form a coherent picture of the question at hand. Simply ignoring the zero observations is likely to lead to biased estimates of the effects of the independent variables.

A different approach, able to account for zero observations properly, was proposed by Drakos et al. in a paper published in 2014. Their idea is to take the dependent variable, portfolio investments in their case, as dichotomous, i.e. taking value 1 if the investment holding is positive and zero otherwise. This allows them to use a panel probit estimation and also to consider a dynamic version of the model. This approach is also useful, if the share of confidential observations in the data is large, as it is in publicly available data on cross-border portfolio investment holdings and also cross-border bank asset holdings. Their approach however is unable to say anything about the determinants of the level of investment holdings, so this too is a too simplistic take on the issue.

Since the first papers estimating gravity equations for financial asset trade, methodological advances have been taken within the international trade literature concerning the estimation technique of the gravity equation. Santos-Silva and Tenreyro (2006) propose an estimation method that is starting to take hold more widely (see e.g. Brei and von Peter, 2018). This method, called

by the authors the Poisson pseudo-maximum-likelihood (PPML) procedure allows for estimating the gravity equations in their multiplicative form, i.e. without log-linearizing the equation. In their paper they show that the usual approach of log-linearizing the model and then estimating it with OLS results in bias through dropping the zero observations and introducing additional heteroskedasticity, which will overstate the distance effect.

My choice is not the PPML, but instead a different way to address the limited nature of my dependent variable. The double-hurdle model has to my knowledge not been employed in the context of cross-border banking before. This model is closely related to tobit models and other models for limited dependent variables and was first suggested by Cragg (1971) for cases where the value of dependent variable is zero with non-negligible probability. In addition to this the double-hurdle model has a specific feature: By assuming two different stages or "hurdles", a dichotomous participation decision followed by a level decision, it allows these two hurdles to be governed by different processes.

The double-hurdle model has previously been employed in set-ups that study e.g. female labor supply or consumption of cigarettes (see e.g. Blundell and Meghir, 1987, and Jones, 1989, for classic papers), both phenomenon characterized by a non-negligible share of zero observations. The context of cross-border banking is a natural application for the double-hurdle model for two reasons. First, because the observations cluster on zero, i.e. the dependent variable is clearly limited. Second, and more specifically, because the decision to extend cross-border credit is intuitively easy to deconstruct into the two hurdles, participation and level decisions. A banker considering extending credit to a given country must first make the dichotomous decision of doing so or not. Then given that the decision to invest is positive, the banker decides the level of credit extended. There is no reason why these decisions should be determined by identical processes.

5.2 The estimations

The full model to be estimated is given by the following equation:

$$\begin{aligned} log(ba_{od,t}) =& \alpha_1 log(GDP_{o,t}) + \alpha_2 log(GDP_{d,t}) + \alpha_3 log(distw_{od}) \\ &+ \alpha_4 mpif_{d,t} + \alpha_5 mpif_{o,t} + \alpha_6 mpib_{d,t} + \alpha_7 mpib_{o,t} \\ &+ \text{gravity controls} \\ &+ \text{controls for financial sophistication} \\ &+ \text{multilateral resistance term} \\ &+ \text{time dummies} \\ &+ \text{constant} + u_{od,t}, \qquad (4) \\ & o, d = 1, ..., 117 \text{ and } t = 1, ..., 14. \end{aligned}$$

In the first specification I include only the economic masses, distance and the macroprudential variables. To the second specification I add the gravity and financial sophistication controls and the regional dummies proxying multilateral resistance. Time dummies and a constant are included in both specifications. The double-hurdle approach entails estimating two equations, which give different marginal effects:

- **The participation equation:** the effect of independent variables on the probability of $ba_{od,t}$ being positive
- **The level equation:** the effect of a change in independent variables on the level of $ba_{od,t}$ conditional on the level being positive

Theory predicts that the marginal effects of the economic masses should be positive and that of distance should be negative. This is indeed the case for all specifications. According to my hypotheses the effects of implementing macroprudential regulation aimed at financial institutions in the destination country ($mpif_{d,t}$) and at borrowers in the origin country ($mpib_{o,t}$) should be positive. The effects of implementing macroprudential regulation aimed at financial institutions in the origin country ($mpif_{o,t}$) and at borrowers in the destination

country ($mpib_{d,t}$) should be negative. This is not consistently confirmed by the results.

5.3 Results (preliminary)

The results of the double-hurdle estimation are given in Table 6. The participation equation determines the effect of the independent variables to the probability of a positive stock of bank assets, corresponding to the dichotomous approach. The level equation determines the effect of the independent variables on the level of the holdings, corresponding to the OLS approach, *given that the holdings are positive*. All variables are included in the participation and the level equation, though this need not be, as different variables may have significant effects on the two decisions.

What I found surprising about these effects is that they are practically all highly statistically significant. I would have expected that the effects for at least mpifo to be less significant. I'm as of yet at least unable to say if this because these indices pick something that I should control in some other way, or if there is a bad endogeneity problem or something going on. This is something I should work on to really try to understand what's going on here. Also the way the hypotheses are sometimes confirmed and sometimes not points out to there being something amiss in either the data or the estimation method or the way I think about the transmission channels.

Interpreting these marginal effects as percent changes in the dependent variable requires some focus. Recall that the equation to be estimated is a combination of log-log and log-lin. Thus the marginal effects are interpreted differently depending on whether the independent variable is in logs or in integers. In a log-log equation, the marginal effect is interpreted as an elasticity, so a one percent change in the independent variable leads to a percent change the size of the marginal effect in the dependent variable. In a log-lin equation, one unit change in the independent variable instead leads to a percent change in the dependent variable, that is roughly hundred times the size of the marginal effect. Thus in for example the second specification, when the macroprudential

Specification	(1)		(2)	
Depvar: $log(ba_{od})$	Participation	Level	Participation	Level
$log(GDP_o)$	0.08****	0.59****	0.08****	0.62****
	(0.00)	(0.01)	(0.00)	(0.01)
$log(GDP_d)$	0.09****	0.60****	0.09****	0.61****
	(0.00)	(0.01)	(0.00)	(0.01)
$log(distw_{od})$	-0.16****	-0.81****	-0.10****	-0.88****
	(0.00)	(0.01)	(0.00)	(0.01)
$mpif_d$	-0.01****	-0.17****	**0.02****	-0.10****
effect positive	(0.00)	(0.01)	(0.00)	(0.01)
$mpif_o$	**-0.02****	**-0.17****	0.02****	**-0.09****
effect negative	(0.00)	(0.01)	(0.00)	(0.01)
$mpib_d$	0.03****	0.28****	**-0.02****	**-0.25****
effect negative	(0.00)	(0.02)	(0.00)	(0.01)
$mpib_o$	**0.02****	**0.32****	-0.00	-0.14****
effect positive	(0.00)	(0.02)	(0.00)	(0.01)
gravity controls	No	No	Yes	Yes
financial soph. ctrls	No	No	Yes	Yes
regional	No	No	Yes	Yes

Significance at the 10%, 5%, 1% and 0.1% levels is denoted by *, **, *** and **** respectively.

Standard errors in parentheses.

The effects that are in line with hypotheses are bolded.

Table 6: Average marginal effects and hypotheses

stance on say capital requirements of a destination country is tightened, i.e. the $mpif_d$ index rises by one unit, the effect on the dependent variable is in fact quite large: The probability of a positive level of international lending between the country pair increases by 2.4 %, and the level of holdings, conditional on them being positive, decreases by 9.8 %.

In Table 7 I have the marginal effects of either a percent change in the

log-variables or a unit change in the integer variables interpreted as percent changes on the probability of dependent variable being positive and on the level of positive holdings. I find some of these effects to be surprisingly large, and would be careful of putting too much weight on the size of these effects at least before proper robustness checks. Some of these feel quite believable, say the 2 % increase in probability of a positive level of international lending after one unit increase in $mpif_o$*, but that the level of positive lending should increase 32 % feels a bit doubtful. It is not however unheard of to fund these average marginal effects on bilateral flows or holdings to be very large, this is a common finding in the literature on gravity in goods trade. It must be because what I measure here is the average marginal effect on the mean of the dependent variable, which is quite small.*

Specification	(1)		(2)	
Depvar: $log(ba_{od})$	Participation	Level	Participation	Level
$log(GDP_o)$, %-change	0.08%	0.59%	0.08%	0.62%
$log(GDP_d)$, %-change	0.09%	0.60%	0.09%	0.61%
$log(distw_{od})$, %-change	-0.16%	-0.81%	-0.10%	-0.88%
$mpif_d$, unit change	-1%	-17%	**2%**	-10%
effect positive				
$mpif_o$, unit change	**-2%**	**-17%**	2%	**-9%**
effect negative				
$mpib_d$, unit change	3%	28%	**-2%**	**-25%**
effect negative				
$mpib_o$, unit change	**2%**	**32%**	*-0%*	-14%
effect positive				
gravity controls	No	No	Yes	Yes
financial soph. ctrls	No	No	Yes	Yes
regional	No	No	Yes	Yes

Significance at the 10%, 5%, 1% and 0.1% levels is denoted by *, **, *** and **** respectively.

Table 7: The percent changes in the dependent variable associated with a change in controls

6 Conclusions

My preliminary results indeed appear to show that the gravity model can be of use in the study of cross-border spillovers of macroprudential regulation through international lending. There is however a clear need for further robustness checks, perhaps using a different estimation method.

The estimation results point to there being statistically significant marginal effects and that these may be non-negligible. As such my result support the findings that there are cross-border spillovers of macrprudential regulation, but I would not be confident enough to use the exact numbers of percent changes just yet.

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