DEUTSCHE BUNDESBANK
EUROSYSTEM

Workshop on

“The Costs and Benefits of International Banking”

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Presentation to

“A gravity equation of bank loans“

A Gravity Equation for Bank Loans

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Introduction

- Gravity equation extremely successful in explaining international bank lending
- Surprising: Transport costs should not matter for cross-border loans
- Our goal: Provide a theoretical foundation for the gravity equation in cross-border lending

A Theory of Aggregate Cross-Border Bank Lending

General Setup

- Starting point: Consider a firm searching for a loan in a number of relevant countries
- Loan offers have various dimensions (interest rate, maturity, timing, collateral...)
- The firm might choose between a number of differentiated loan offers
- Decision rule: Choose the loan that minimizes overall borrowing costs
- Cost components: Interest rate, loan and bank specific cost factors
- Only some of the relevant cost components observable

A Theory of Aggregate Cross-Border Bank Lending

Cost Components

Cost components are:

- **Interest Rate**, which is influenced by:
  - average bank lending rate in lending country j, r_j: observable
  - monitoring, search and contracting costs: unobservable but depend systematically on distance (and distance related variables) τ_{ij}
- **Average bank characteristics in lending country** j that affect the cost of the loan (a_j)

Total borrowing cost can be written as

$$c_{igjk} = \underbrace{\beta r_j + \gamma \tau_{ij} + \delta a_j}_{\bar{c}_{ij}} + \varepsilon_{igjk}$$

- ε_{igjk} random components unobservable to the researcher
- $\bar{c}_{ij}$ average costs of borrowing from country j

A Theory of Aggregate Cross-Border Bank Lending

The Firm's Problem

- The probability that firm g from i chooses bank k from j is

$$\mathbf{P}_{igjk} = \Pr\left(\bar{c}_{ij} + \varepsilon_{igjk} = \min\left\{\bar{c}_{il} + \varepsilon_{iglh}\right\}\right)$$
$$\mathbf{P}_{igjk} = \Pr\left(\bar{c}_{ij} + \varepsilon_{igjk} < \bar{c}_{il} + \varepsilon_{igl1};\ldots;\bar{c}_{ij} + \varepsilon_{igjk} < \bar{c}_{il} + \varepsilon_{igln_l}\right)$$
$$= 1 - \Pr\left(\bar{c}_{ij} - \bar{c}_{il} + \varepsilon_{igjk} \geq \varepsilon_{igl1};\ldots;\bar{c}_{ij} - \bar{c}_{il} + \varepsilon_{igjk} \geq \varepsilon_{igln_l}\right)$$

- $\forall\ l = 1\ldots N$ (country index); $h = 1\ldots n_l$ (banks in country l); $jk \neq lh$

- Denote with $F(\cdot)$ the cumulative density function of ε
- For any x of ε_{igjk} bank loan variant jk is chosen with probability

$$\mathbf{P}_{igjk} = \prod_{l=1}^{N}\prod_{l=1}^{n_l}\left[1 - F(\bar{c}_{ij} - \bar{c}_{il} + x)\right]$$
$$\mathbf{P}_{igjk} = \prod_{l=1}^{N}\left[1 - F(\bar{c}_{ij} - \bar{c}_{il} + x)\right]^{n_l}$$

Parameterization

What is $F(\cdot)$?

- Interest in the minimum realizations of the random component ε_{igjk}
- We assume the minima of ε_{igjk} are Gumbel distributed
- The probability of choosing bank k in j is then (Anderson, de Palma, Thisse '92)

$$P_{ijk} = \frac{\exp\left(-\frac{\bar{c}_{ij}}{\sigma}\right)}{\sum_{l=1}^{N} n_l \exp\left(-\frac{\bar{c}_{il}}{\sigma}\right)}$$

The Gravity Equation for Bank Loans

- Aggregating over all n_j banks in country j gives

$$\mathbf{P}_{ij} = n_j \exp\left(-\frac{\bar{c}_{ij}}{\sigma}\right) / \sum_{l=1}^{N} n_l \exp\left(-\frac{\bar{c}_{il}}{\sigma}\right)$$

- $\rightarrow$ the probability of choosing **any** loan from country j
- Multiplying with total loans BL_i in country i gives

$$BA_{ji} = \frac{n_j \exp\left(-\frac{\beta r_j + \gamma \tau_{ij} + \delta a_j}{\sigma}\right)}{\sum_{l=1}^{N} n_l \exp\left(-\frac{\beta r_l + \gamma \tau_{il} + \delta a_l}{\sigma}\right)} BL_i \qquad (1)$$

$\Rightarrow$ total cross-border loans $\boldsymbol{BA_{ji}}$ from country $\boldsymbol{j}$ to country $\boldsymbol{i}$

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$$\boldsymbol{BA_{ji}} = \frac{\boldsymbol{n_j \exp\left(-\frac{\beta r_j + \gamma \tau_{ij} + \delta a_j}{\sigma}\right)}}{\boldsymbol{\sum_{l=1}^{N} n_l \exp\left(-\frac{\beta r_l + \gamma \tau_{il} + \delta a_l}{\sigma}\right)}} \boldsymbol{BL_i} \tag{1}$$

$\Rightarrow$ total cross-border loans $\boldsymbol{BA_{ji}}$ from country $\boldsymbol{j}$ to country $\boldsymbol{i}$

Empirics

The Empirical Gravity Equation

- Consider again the gravity equation for bank loans

$$BA_{ji} = \frac{n_j \exp\left(-\frac{\beta r_j + \gamma \tau_{ij} + \delta a_j}{\sigma}\right)}{\sum_{l=1}^{N} n_l \exp\left(-\frac{\beta r_l + \gamma \tau_{il} + \delta a_l}{\sigma}\right)} BL_i$$

- Country i-specific fixed effects D_i control for the denominator
- Country j-specific fixed effects D_j control for banking characteristics a_j

- The empirical gravity equation then reads

$$BA_{ji} = \exp\left[\left(\beta_1 r_j + \beta_2 \tau_{ij} + D_j - D_i\right)\right] n_j^{\beta_3} BL_i^{\beta_4} \varepsilon_{ij}$$

Empirics

Method

- Take logs of both sides and estimate FE-OLS

$$ln\, BA_{ji} = \beta_1\, r_j + \beta_2\, \tau_{ij} + \beta_3\, ln\, n_j + \beta_4\, ln\, BL_i + D_i + D_j + ln\, \varepsilon_{ij}$$

→ Silva & Tenreyro ('06): linearization might introduce substantial biases

- Poisson estimator allows estimating Gravity equations in multiplicative form

$$BA_{ji} = exp\left[\beta_1\, r_j + \beta_2\, \tau_{ij} + \beta_3\, ln\, n_j + \beta_4\, ln\, BL_i + D_i + D_j\right] \varepsilon_{ij}$$

- The panel versions of the gravity equation read as follows

$$ln\, BA_{jit} = \beta_1\, r_{jt} + \beta_2\, \tau_{ij} + \beta_3\, ln\, n_{jt} + \beta_4\, ln\, BL_{it} + D_{it} + D_{jt} + ln\, \varepsilon_{ijt}$$

$$BA_{jit} = exp\left[\beta_1\, r_{jt} + \beta_2\, \tau_{ij} + \beta_3\, ln\, n_{jt} + \beta_4\, lnBL_{it} + D_{it} + D_{jt}\right] \varepsilon_{ijt}$$

Empirics

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- **Time-varying country-specific fixed effects**

Data

- Investigation period: 2000 to 2006
- Data from several sources:
  - BIS - confidential locational bilateral banking statistics
  - Financial Structure Database (Beck et al 2009)
  - OECD Banking Statistic on income statement and balance sheet
  - CEPII
  - Worldwide Governance Indicator

Main Results I

Panel gravity equation for cross-border bank lending

	PPML	OLS	OLS (1+BA_{ij})
BL_i	0.558***	0.596***	0.624***
	[0.050]	[0.035]	[0.035]
$dist_{ij}$	-0.368***	-0.852***	-0.881***
	[0.030]	[0.035]	[0.037]
n_j	0.369***	0.724***	0.652***
	[0.067]	[0.070]	[0.090]
r_j	-0.145**	-0.041	-0.085**
	[0.069]	[0.039]	[0.039]
N	5209	4895	5209
R^2	0.819	0.728	0.731
RESET Test (p-value)	0.701	0.024	0.010
Park-Test (p-value)	0.000	-	-
GNR (p-value)	0.113	-	-

The dependent variable are assets of reporting country j in country i. BL_i = total bank loan in receiving country i. $dist_{ij}$ = distance between reporting country j and receiving country i. n_j = inverse of the 3-bank concentration ratio in country j. r_j = average implicit bank lending rate in country j. The RESET-test tests the Null of no neglected nonlinearities. The Park-test tests the Null that the model is consistently estimated by OLS. The GNR test checks the assumption of the Poisson estimator that the conditional variance is proportional to the conditional mean. Robust standard errors in brackets. ***, **, * indicate significant at the 1, 5, 10 % level.

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Main Results II

Effects of theory derived fixed effects

	Benchmark	both country fixed effects + year controls ignoring time variation	sending country fixed effects + year controls ignoring time variation	receiving country fixed effects + year controls ignoring time variation	year controls
BL_i	0.558***	0.597***	0.694***	0.619**	0.644***
	[0.050]	[0.162]	[0.019]	[0.250]	[0.024]
$dist_{ij}$	-0.368***	-0.328***	-0.446***	-0.427***	-0.505***
	[0.030]	[0.030]	[0.024]	[0.048]	[0.034]
n_j	0.369***	0.043	0.048	0.444***	0.409***
	[0.067]	[0.093]	[0.108]	[0.035]	[0.038]
r_j	-0.145**	-0.071	-0.08	-0.118***	-0.118***
	[0.069]	[0.044]	[0.063]	[0.030]	[0.036]
N	5209	5209	5209	5209	5209
R^2	0.819	0.668	0.375	0.287	0.268

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	[0.069]	[0.044]	[0.063]	[0.030]	[0.036]
N	5209	5209	5209	5209	5209
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Application I

Effects of banking market characteristics

	(1)
BL_i	0.566***
	[0.050]
$dist_{ij}$	-0.365***
	[0.030]
n_j	0.445***
	[0.072]
r_j	-0.105*
	[0.054]
$margin$	-0.227***
	[0.080]
roa	-0.086
	[0.139]
$cost - inc$	-0.025***
	[0.009]
N	5209
R^2	0.821

Application II

Search and Contracting Costs

	(1)
BL_i	0.565***
	[0.051]
$dist_{ij}$	-0.412***
	[0.039]
n_j	0.382***
	[0.066]
r_j	-0.156**
	[0.067]
contig	-0.133
	[0.106]
comlang	-0.058
	[0.098]
comlegor	0.505***
	[0.056]
N	5209
R^2	0.840

Application III

Monitoring Costs

	(1)	(2)	(3)	(4)	(5)	(6)
BL_i	0.529***	0.551***	0.515***	0.540***	0.527***	0.541***
	[0.053]	[0.058]	[0.053]	[0.054]	[0.055]	[0.055]
$dist_{ij}$	-0.357***	-0.366***	-0.353***	-0.363***	-0.357***	-0.363***
	[0.030]	[0.030]	[0.030]	[0.030]	[0.031]	[0.030]
n_j	0.370***	0.370***	0.371***	0.371***	0.371***	0.370***
	[0.066]	[0.067]	[0.063]	[0.067]	[0.065]	[0.066]
r_j	-0.146**	-0.145**	-0.144**	-0.146**	-0.144**	-0.145**
	[0.068]	[0.069]	[0.066]	[0.069]	[0.067]	[0.068]
voice	0.263**					
	[0.118]					
ruleoflaw		0.034				
		[0.134]				
regul			0.380**			
			[0.148]			
polstab				0.143		
				[0.121]		
gov					0.189	
					[0.133]	
corrupt						0.093
						[0.111]
N	5187	5187	5187	5187	5187	5187
R^2	0.821	0.82	0.822	0.82	0.821	0.82

Application III

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	(1)	(2)	(3)	(4)	(5)	(6)
BL_i	0.529***	0.551***	0.515***	0.540***	0.527***	0.541***
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	[0.030]	[0.030]	[0.030]	[0.030]	[0.031]	[0.030]
n_j	0.370***	0.370***	0.371***	0.371***	0.371***	0.370***
	[0.066]	[0.067]	[0.063]	[0.067]	[0.065]	[0.066]
r_j	-0.146**	-0.145**	-0.144**	-0.146**	-0.144**	-0.145**
	[0.068]	[0.069]	[0.066]	[0.069]	[0.067]	[0.068]
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$dist_{ij}$	-0.357***	-0.366***	-0.353***	-0.363***	-0.357***	-0.363***
	[0.030]	[0.030]	[0.030]	[0.030]	[0.031]	[0.030]
n_j	0.370***	0.370***	0.371***	0.371***	0.371***	0.370***
	[0.066]	[0.067]	[0.063]	[0.067]	[0.065]	[0.066]
r_j	-0.146**	-0.145**	-0.144**	-0.146**	-0.144**	-0.145**
	[0.068]	[0.069]	[0.066]	[0.069]	[0.067]	[0.068]
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Summary

- We provide a theoretical foundation for a gravity equation for cross-border bank lending
- The theory explains the role of distance in international bank lending:
  - distance raises firm's cost when screening remote banking markets
  - distance increases monitoring costs for banks
- The gravity equation features multilateral (cost) resistance terms and unobserved lending country characteristics
- These unobserved effects need to be accounted for when applying gravity framework to cross-border loan data
- Empirical implementation lends strong support to the predictions of our theoretical model

Gumbel Distribution

Jump Back

- The Gumbel distribution has a double exponential form.

$$F(x) = 1 - \exp\left[-\exp\left(\frac{x}{\sigma} - \gamma\right)\right] \tag{2}$$

- with σ a constant scale parameter describing the "horizontal stretching" , and γ the Euler's constant.
- The density function $f(x)$ can be derived as

$$f(x) = \frac{1}{\sigma}\exp\left(\frac{x}{\sigma} - \gamma\right)\left\{\exp\left[-\exp\left(\frac{x}{\sigma} - \gamma\right)\right]\right\}.$$

Application Back-up

Effects of banking market characteristics

Jump Back

	Benchmark	both country fixed effects + year controls ignoring time variation	sending country fixed effects + year controls ignoring time variation	receiving country fixed effects + year controls ignoring time variation	year controls
BL_i	0.566***	0.607***	0.694***	0.646***	0.653***
	[0.050]	[0.162]	[0.019]	[0.243]	[0.024]
$dist_{ij}$	-0.365***	-0.328***	-0.446***	-0.431***	-0.506***
	[0.030]	[0.030]	[0.024]	[0.049]	[0.034]
n_j	0.445***	-0.005	0.001	0.533***	0.484***
	[0.072]	[0.099]	[0.117]	[0.040]	[0.041]
r_j	-0.105*	-0.066	-0.074	-0.019	-0.026
	[0.054]	[0.044]	[0.063]	[0.023]	[0.027]
$margin$	-0.227***	-0.082	-0.081	-0.257***	-0.220***
	[0.080]	[0.060]	[0.074]	[0.035]	[0.038]
roa	-0.086	0.019	0.011	-0.402***	-0.421***
	[0.139]	[0.048]	[0.063]	[0.052]	[0.052]
$cost-inc$	-0.025***	-0.002	-0.002	-0.012***	-0.014***
	[0.009]	[0.003]	[0.004]	[0.003]	[0.003]
N	5209	5209	5209	5209	5209
R^2	0.821	0.834	0.669	0.411	0.318

Application II Back-up

Search and contracting costs

Jump Back

	Benchmark	both country fixed effects + year controls ignoring time variation	sending country fixed effects + year controls ignoring time variation	receiving country fixed effects + year controls ignoring time variation	year controls
BL_i	0.565***	0.593***	0.695***	0.623**	0.648***
	[0.051]	[0.155]	[0.019]	[0.248]	[0.025]
$dist_{ij}$	-0.412***	-0.390***	-0.516***	-0.315***	-0.504***
	[0.039]	[0.039]	[0.035]	[0.057]	[0.045]
n_j	0.382***	0.033	0.044	0.415***	0.405***
	[0.066]	[0.085]	[0.104]	[0.035]	[0.036]
r_j	-0.156**	-0.064	-0.074	-0.112***	-0.119***
	[0.067]	[0.040]	[0.059]	[0.030]	[0.036]
contig	-0.113	-0.113	-0.429***	0.516***	-0.027
	[0.106]	[0.103]	[0.107]	[0.134]	[0.152]
comlang	-0.058	-0.073	0.115	-0.14	-0.021
	[0.098]	[0.107]	[0.135]	[0.123]	[0.138]
comlegor	0.505***	0.554***	0.260***	0.143	0.131
	[0.056]	[0.055]	[0.083]	[0.104]	[0.090]
N	5209	5209	5209	5209	5209
R^2	0.84	0.853	0.663	0.379	0.287

The Log of Gravity

Consider the stochastic version of a gravity equation:

$$y = exp(x'b) + \varepsilon$$

Define η as $\eta = 1 + \varepsilon / exp(x'b)$ with $E(\eta|x) = 1$, then above can be written as

$$y = exp(x'b)\ \eta$$

The standard approach is taking logs of both sides

$$ln\ y = (x'b) + ln\ \eta$$

To obtain a consistent estimator of the parameters using OLS, it is necessary that $E(ln\ \eta|x)$ is independent of x (or even that $E(ln\ \eta|x) = 0$). This condition is met only if ε can be written as $\varepsilon = exp(x'b)v$, where v is a random variable statistically independent of x. In this case, $\eta = 1 + v$ and therefore is statistically independent of x, implying that $E[ln\ \eta|x]$ is constant.Thus, only under very specific conditions on the error term is the log linear representation of the constant-elasticity model useful as a device to estimate the parameters of interest.