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Relationship Banking, Liquidity, and Investment in the German Industrialization

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ABSTRACT

Close bank relationships are thought to ameliorate firms' liquidity constraints—a phenomenon frequently measured by liquidity sensitivity of investment. Using German firms during the formative years of universal banking (1903–1913), this paper shows that, even controlling for selection bias, investment is more sensitive to internal liquidity for bank-networked firms than unattached firms. The firm exhibiting the greatest liquidity sensitivity, however, faced no apparent liquidity constraint. The findings yield two implications: they support recent research rejecting a linear relationship between liquidity sensitivity and financing constraints, and they suggest that relationship banking provides no consistent lessening of firms' liquidity sensitivity.

As banking regulation loosens in the United States and efforts toward industrial redevelopment in eastern Europe intensify, universal banking is attracting a great deal of attention. Germany and Japan, whose large universal banks are often credited with the post-World War II industrial successes of these economies, have been singled out as the prime examples of the beneficial effects of bank-firm relationships.[1] These banks are thought to foster long-term relationships with industrial firms, promoting more efficient and stronger investment. Powerful influence has been attributed to

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[1] Schumpeter (1939) and Gerschenkron (1962) popularize general notions about the importance of universal banking in industrialization. Tilly (1992) espouses a more moderate view. Contrary views can be found in Wellhöner (1989).

Germany's universal banks, yet little systematic evidence has been provided to support these assertions. This paper presents new evidence on the role of the German universal banks during the period of heavy industrialization in the decade preceding World War I. Study of this country and period is particularly important given the extent to which modern conceptions of relationship banking are based on the accepted wisdom about prewar Germany.

By investigating the influence of universal banking relationships on the investment patterns of industrial firms, this paper measures one component of the hypothesized impact of bank-based financial systems on industrial growth. The methodology is based partly on what has become an extensive literature on financing constraints, in which authors test the empirical disparity in liquidity sensitivity of investment according to a priori assumptions about the difference in information problems faced by individual firms. This approach is suggested by Fazzari, Hubbard, and Petersen (1988), though that study does not address bank-firm relationships.[2] Previous studies typically find higher cash-flow sensitivity for firms considered to be unattached to a bank than for firms with bank connections. Such findings are taken as evidence of the role of relationship banking in reducing information asymmetries between investors and savers.

Empirical studies of the importance of banking relationships are grounded in theoretical models of investment in situations of asymmetric information and incomplete contracts.[3] These models, connecting capital market imperfections with the relative costliness of external finance, indicate a potential role for banks in monitoring entrepreneurs. Monitoring may provide banks or investors with better information about their clients' investment opportunities than would otherwise become available. Previous authors argue that, because of this attenuation of asymmetric information problems, a firm's investment will depend on the existence of new projects and not on the availability of internal funds. Unmonitored firms, who cannot defend the viability of each project to individual investors, must time investments according to their liquidity. According to this logic, investment should, therefore, be more sensitive to internal funds for unattached firms than for attached firms.

[2] Of greatest relevance to German-style universal banking are the studies by Hoshi, Kashyap, and Scharfstein (1991) on post-war Japanese industrial groups; Elston (1998) on modern German industrial firms; and Ramírez (1995) on J.P. Morgan's group in the United States at the beginning of this century. See Chirinko (1995), Houston and James (1996), and Petersen and Rajan (1994) for related work. Fundamentally, these studies are based on a long-standing literature on the determinants of industrial investment in general. See Kuh (1963), and Meyer and Kuh (1957). Hubbard (1998) reviews much of the literature on investment and financing constraints.

[3] See Grossman and Hart (1982), Jensen and Meckling (1976), Myers and Majluf (1984), Stiglitz and Weiss (1981), and Stulz (1990). Diamond's (1984) delegated monitoring framework offers an intuitive explanation for the existence of financial intermediaries based on the possibility of moral hazard problems.

Because of long-term efficiency gains, the effects of bank affiliations may become more pronounced with time. Attached firms' liquidity sensitivity of investment, while perhaps equal to that of independent firms in the short run, should be lower in the long run. Distinguishing between static and dynamic effects requires some adjustment of the standard empirical specification. By including measures of long-term bank-firm relationships, this paper measures the dynamic effects of bank involvement.

Since bank attachment may be endogenous, it may be inappropriate to assign a causal relationship between bank attachment and firms' liquidity sensitivity of investment. Although some previous studies attempt to address selectivity bias on the basis of qualitative arguments or comparisons of sample means, none attempts to model selectivity bias directly. This study takes steps toward accounting for such problems using two-stage models of investment and attachment. The results indicate that selection bias, to the extent it can be measured, does not account for the findings in this study.

Despite the voluminous research using liquidity sensitivity to identify firm liquidity constraints, recent work is beginning to question this approach. In particular, Kaplan and Zingales (1997) challenge the methodology and results of Fazzari et al. (1988) and suggest that a simple test of the sensitivity of investment to internal funds does not fully capture the effects of liquidity constraints faced by industrial firms.[4] Indeed, according to Kaplan and Zingales, liquidity sensitivity of investment bears no consistent relation to financing constraints.

In contrast to several recent studies, this paper demonstrates that bank attachment is not associated with dramatic reductions in firms' liquidity sensitivity of investment. In some cases, bank-attached firms experienced higher liquidity sensitivity than unattached firms. Furthermore, firms with long-term bank relationships—those with bank attachments in the five years prior to the period investigated—experienced no generalizable reduction in liquidity sensitivity. Moreover, bank attachment is not associated with high rates of investment. Critically, however, the firm for which estimated liquidity sensitivity was the highest showed no real signs of liquidity constraints.

The results of this study therefore yield two types of conclusions. With respect to methodology, the findings support the hypothesis that firms' liquidity sensitivity of investment may provide misleading predictions about financing constraints. On the substantive front, if liquidity sensitivity does signal investment inefficiencies, then the results suggest limited benefits of relationship banking for industrial investment.

The remainder of the paper is organized as follows. Section I describes the data as well as methods for determining bank-firm relationships. Section II presents the fixed effects model and results and Section III extends the model

[4] See the response by Fazzari, Hubbard, and Petersen (1996) for criticism of Kaplan and Zingales (1997).

to a random effects framework with corrections for potential selectivity bias and also reviews a discrete-choice model of bank affiliation. Section IV concludes.

I. Data

Universal banks arose on the European continent in the nineteenth century and became particularly prevalent in Germany. In addition to traditional commercial banking activities, the universal banks were actively involved in the underwriting, issue, and brokerage of industrial securities.[5] German joint-stock companies mainly used banks as financial intermediaries, rather than raising funds directly from the public.[6] The nine largest universal banks became known as the great banks, and, after several mergers, three of these banks remain in operation today. For the purposes of this study, all other joint-stock universal banks are categorized as small (or provincial) banks.

A. Sources

The data for this study come from Part II of *Saling's Börsen-Jahrbuch*, a stock market annual that began publishing in 1876 and was targeted toward bankers and investors. The data appear to be derived from the annual reports (*Jahresberichte*) of the firms. The sample in this paper comprises 75 firms of two basic types—long-lived firms and newly public firms. The first group includes 50 firms covering the period 1903 to 1913. Selection is limited to those firms in continuous existence from 1880 (1883 for one firm) to 1913. There is no entry into or exit out of the sample, and thus, the panel is nearly balanced. Exceptions arise when variables are missing for a given firm-year, but these cases are rare. The data are sampled from the 1900 volume of *Saling's* and reflect the sectoral distribution of joint-stock companies reported there. The sample is also structured to represent the size and geographical variation of reported (Berlin-listed) firms.[7]

Because of the constraints imposed on the selection of long-lived firms, I augment the data with a random sample of newly public firms. This group consists of a panel of 25 firms whose initial public offerings (IPOs) fell between 1880 and 1899. Like the first group of firms, the new firms are selected from those with entries published in the 1900 issue of *Saling's*. Since firms are permitted to exit the sample at any time after the sampling date, and since a few companies exited before the end of the period, the resulting panel is somewhat unbalanced. The IPO firms represent a random cross-

[5] For details, see Bosenick (1912), Jeidels (1905), Riesser (1910), and Whale (1930).

[6] The banks' active role in the promotion, placement, and trading of securities apparently reduced the importance of the stock exchange. The German capital market remains underdeveloped relative to its modern counterparts—particularly in Britain and the United States.

[7] The long-lived firms were chosen and the firms' financial data were collected by Rudi Rettig. See Rettig (1978).

section of joint-stock firms founded between 1880 and 1900 that were listed in Berlin in 1900.[8] The two groups of firms complement one another by providing a comparison of effects during early and later stages of the firm's development.

B. Measuring Bank Affiliation

German corporate governance forms, which differ significantly from the Anglo-American board of directors, have changed little over the past century. Joint-stock companies are governed by two separate bodies: the executive board (*Vorstand*) is made up of firm managers, while the supervisory board (*Aufsichtsrat*) comprises shareholders' representatives. At the turn of the century, members of the supervisory board did not play an active role in firms' day-to-day operations; but they are thought to have wielded considerable influence in long-run investment and strategic planning. In addition to direct power through voting rights, positions on firms' boards are thought to have allowed banks access to the inner workings of the firms they financed. Equity ownership, it should be noted, was not a prerequisite for membership in the supervisory board. Unfortunately, since firms were not required to report shareholders information (in the pre-war period), no comprehensive data on ownership structure exist.

The placement of bank directors on firms' boards of directors is commonly perceived as evidence of a close firm-bank relationship, and the institution of interlocking directorates has become a trademark of German-style universal banking. In 1905, Otto Jeidels maintained that "...the power of the Great Banks is exercised via the legal institution of the *Aufsichtsrat*, rather than through direct influence of financial strength."[9]

Given the dual structure of German company directorates, there are four ways in which a firm might be considered to have interlocking directorates with a bank. The narrowest view of bank-firm relationships considers only bank executive board members sitting on firms' supervisory boards. Such a restriction, however, eliminates firms with the three other types of links to banks—potentially important conduits for information and oversight. The same individual could have sat simultaneously on bank and firm executive boards or on bank and firm supervisory boards. Finally, firm executive board members sometimes sat on bank supervisory boards. Therefore, in addition to the narrow definition of bank involvement, this paper adds a second measure that includes all possible bank connections.

Interlocking directorates are identified by cross-referencing the executive and supervisory board members of the firms in the samples with those of the principal universal banks for 1905 and 1910. In the few cases in which status changed, I assume that the status changed midway through the period.

[8] For further details on sample selection, see Fohlin (1994). The dating of IPOs is chosen to partly offset the bias introduced into the first group of firms by the criterion of pre-1880 founding.

[9] Jeidels (1905), p. 145, author's translation. See also Gerschenkron (1962).

C. Descriptive Statistics

The firms' financial variables are defined as follows. Fixed capital includes land, property, plant, equipment, patents, and permits and excludes inventories (since inventories are likely to decline when production increases), and investment is the first difference of gross fixed capital. Short-term liquidity is the sum of assets available on short notice, such as cash, notes, bank deposits, and accounts receivable; while stock liquidity is the sum of short-term liquidity and longer-term financial wealth, such as securities. Revenues and profits are as reported in the profit and loss statements of the firms; and inside finance (alternatively, net worth) is share capital plus reserves. Investment, liquidity, profits, and revenues are all normalized by the yearly stock of fixed capital.

Cash flow is represented by after-tax profits. Depreciation allowance is not included, because it was inconsistently taken and reported. Tobin's q cannot be measured directly from the available data because some components of the measure are not documented for the sampled firms. *Saling's* does report the ratio of market to par (book) value of common stocks (called *Kurs)*, and this provides a proxy for marginal common-equity q.

Table I compares sample means for four subpopulations of firms: firms with attachment only to small banks, firms with attachment only to the great banks, firms with attachment to both great banks and other banks, and firms with no attachment to a bank. Data for IPO firms and long-lived firms are given separately. Means are calculated by firm-years, so that the few firms that changed status midperiod fall into the appropriate categories in each year. Several means that appear to be different across bank-attachment categories are insignificantly so due to high standard deviations.[10]

Perhaps of greatest interest for this study is the similarity in investment rates among different categories of bank attachment and between IPO and long-lived firms. Indeed, only the difference of means between great-bank and combined-bank firms within the long-lived sample obtains statistical significance. Nonetheless, the large apparent differences in investment rates suggest variation in the distribution of normalized investment according to subgroup. The discrete-choice model in the final section of the paper pursues this issue further.

Fixed capital and net worth provide two measures of firm size, and Table I reveals a striking difference in these variables between attached and independent firms as well as between IPO firms and long-lived firms. On average, long-lived, great-bank firms maintained more than twice the net worth of their counterparts without great-bank connections, and firms with both great- and small-bank attachment had almost ten times the inside finance of unattached and small-bank-only firms. Similar relationships arise for fixed capital. Among IPO firms, firms with great-bank attachments are also the

[10] Significance test results are available from the author.

Table I

Sample Means by Firm Type

Variables are calculated for all firm-years fitting the criteria. Long-lived firms are those in continuous existence between 1880 and 1913. IPO (initial public offering) firms are those whose initial public offering occurred in or after 1880. Great banks consist of the nine largest Berlin-centered joint-stock banks, small banks are all others, and combined banks refers to affiliation with a combination of great and small banks. Investment, financial assets (cash, bank balances, securities, for example), revenues, and profits are normalized by the stock of fixed assets at the beginning of the period. Net worth (share capital plus reserves) and fixed assets are given in thousands of Marks. Standard deviations are in parentheses.

	Attachments of Long-Lived Firms				Attachments of IPO Firms			
Variable	No Bank	Small Bank	Great Bank	Combined Bank	No Bank	Small Bank	Great Bank	Combined Bank
Investment	0.02	0.05	0.02	0.06	0.00	0.00	0.11	0.03
	(0.13)	(0.28)	(0.10)	(0.21)	(0.04)	(0.10)	(0.41)	(0.16)
Short-term financial assets	0.42	0.83	0.47	0.50	0.59	1.95	0.21	0.63
	(0.63)	(1.02)	(0.30)	(0.65)	(0.26)	(2.83)	(0.22)	(1.35)
Total financial assets	0.50	1.30	0.68	0.75	1.05	2.29	0.22	0.73
	(0.65)	(2.14)	(0.52)	(0.95)	(0.73)	(2.96)	(0.22)	(1.40)
Revenues	0.43	0.62	0.26	0.28	0.32	2.07	0.24	0.39
	(0.33)	(0.54)	(0.18)	(0.22)	(0.16)	(4.04)	(0.14)	(0.31)
Profits	0.13	0.26	0.12	0.13	0.02	0.20	0.06	0.18
	(0.16)	(0.31)	(0.10)	(0.11)	(0.16)	(0.25)	(0.05)	(0.25)
Debt/equity ratio	0.59	0.59	0.55	0.61	0.55	0.96	0.88	0.57
	(0.40)	(0.34)	(0.25)	(0.52)	(0.33)	(0.91)	(0.56)	(0.50)
Tobin's marginal q	1.66	2.12	1.84	2.01	1.00	1.18	1.45	1.83
	(0.86)	(1.35)	(0.95)	(0.74)	(0.36)	(0.39)	(0.21)	(0.75)
Net Worth	5,033	4,749	10,708	39,809	3,103	3,219	8,650	6,285
	(4,940)	(4,467)	(8,305)	(43,186)	(1,343)	(2,150)	(7,506)	(7,583)
Fixed assets	5,940	4,159	7,505	40,838	2,216	2,712	15,080	7,327
	(6,771)	(6,635)	(4,381)	(50,838)	(1,214)	(2,747)	(15,286)	(7,815)
Age (years)	37.6	41.0	42.3	42.3	13.5	16.2	17.7	14.3
	(6.3)	(7.1)	(7.14)	(11.3)	(6.7)	(7.3)	(7.1)	(5.8)
Number of firms	15	18	7	15	5	9	5	15

largest; however, the combined-bank firms tend to have less fixed capital than great-bank-only firms. Not surprisingly, the long-lived firms are larger than IPO firms using either measure.

Relative to their fixed capital, small-bank firms lie at the high end of the distribution for short-term and total financial assets, revenues, and net profits. IPO firms as a group have higher (normalized) revenues and short-term liquid assets, yet they have profits and total financial assets on par with long-lived firms. The differences among the sample populations warn of possible selectivity biases that should be, and are, accounted for in the econometric analysis that follows.

II. Fixed Effects Specifications and Results

Tobin's q theory of investment, and Hayashi's (1982) interpretation thereof, provides the theoretical framework behind several recent empirical studies of firms' investment behavior. In this framework, internal funds play no role in firms' investment decisions; only expected future profitability of investment enters consideration. Such models require strong assumptions. In particular, markets and firm competition must be perfect—two assumptions that are clearly violated for the present case. The fact that liquidity constraints may, therefore, be a real problem motivates the inclusion of inside funds in the investment regression equation.

A. The Fixed Effects Model

The empirical implementation of the Tobin's q model encounters several difficulties. Even in the case of modern data, Tobin's q is notoriously difficult to measure.[11] Dependence on stock market data may present a further complication in the German case. Given the close involvement of the universal banks in the stock market, both par values and market values of shares could well be distorted. For example, in order to unload their shares of issues they no longer wanted to hold, the banks are thought to have propped up share prices occasionally. Such activities would give the false impression that the firm in question had particularly good future investment prospects. Unfortunately, there is no practical solution to this problem at present, but the pervasiveness of such activities by the banks deserves further attention.

Another potential ambiguity in the interpretation of inside funds in the investment equations arises from the possibility that liquidity proxies for production. High levels of production in one period may lead to the need for more capacity in the next period. To control for this potential accelerator effect, lagged production or production growth is often included among the exogenous variables despite the lack of strong theoretical motivation. Since

[11] Hall (1991), Kaplan and Zingales (1996), and Whited (1992) all employ an alternative approach based on estimating Euler equations of investment dynamics.

production data are not available for the current sample, I use revenue growth as the nearest alternative. The reduced form investment equation to be estimated is the following:

$$\frac{I_{it}}{K_{it-1}} = b_1 \frac{I_{it-1}}{K_{it-2}} + b_2 \frac{L_{it-1}}{K_{it-1}} + b_3 Y_{it-1} + b_{4j} Q_{it-1}$$

$$+ b_{5j} B_{jt} \frac{L_{it-1}}{K_{it-1}} + b_{6j} B_{jt} Y_{it-1} + b_{7j} B_{jt} Q_{it-1} + b_{8t} T_t + \epsilon_{it} \quad . \qquad (1)$$

Thus, investment is regressed on lagged (beginning of period) investment (I), liquidity (L), revenue growth (Y), and Tobin's q (Q); indicator variables for attachment to a small bank, a great bank, and a combination of small and great banks (B_j) interacted with each exogenous variable; and annual indicator variables (T_t). Liquidity is represented by cash flow and the stock of liquid assets. Investment, Tobin's q, and revenue growth are as previously defined, and all level variables are normalized by the beginning-of-period stock of fixed capital to reduce the possibility of heteroskedasticity and to control for size effects. The interaction terms allow a comparison of various coefficients between bank-attached and independent firms within the same regression equation.[12]

This basic specification is essentially the same as those used in other recent studies. Stock liquidity is included alone for some specifications for two reasons. First, the stock of financial assets at the beginning of the period seems to be a more sensible representation of a firm's available finance than cash flow. Second, since cash flow and stock liquidity are approximately 80 percent correlated in this sample, and since they are thought to measure similar financial characteristics, inclusion of both variables creates the potential for collinearity problems.

The panel structure of the data leads to regression equations of the form $Y_{it} = X_{it}\,\beta + \epsilon_{it}$, for $I = 1, 2, \ldots N$ and $t = 1, 2, \ldots T_i$, where $\epsilon_{it} = \alpha_i + \eta_{it}$. This specification allows insights into the dynamics of firm investment, but in doing so, it introduces the possibility of correlation over time. Accordingly, I make the standard panel assumptions about the error distributions:

1. The expected values of the error components (α_i and η_{it}) are zero.
2. The components are uncorrelated ($E(\alpha_i \eta_{it}) = 0$).
3. The firm-specific errors are uncorrelated ($E(\epsilon_{it}\epsilon_{jt}) = 0,\ i \neq j$).
4. There is no serial correlation within individual cases' error terms ($E(\eta_{it}\eta_{it'}) = 0,\ t \neq t'$).
5. η_{it} is i.i.d. within groups.
6. α_i is i.i.d.

[12] This approach is analogous to running separate regressions for each category of firm, but using one regression spares degrees of freedom.

The investment equations are estimated using both the standard within groups (fixed effects) method and, in the following section, a generalized least squares (GLS, random effects) framework. The within groups estimation runs ordinary least squares (OLS) on the variables minus their time averages and is equivalent to a pooled regression in which indicator variables are included for each firm.

Clearly, selectivity bias in the choice of bank attachments may drive apparent differences in coefficient estimates; characteristics that cause firms to become involved with banks may simultaneously lead to diminished or heightened liquidity sensitivity. Since it is constant across time, the error component sensitive to endogeneity, α_i, is removed in the case of the within groups estimator. If biases arise at the firm level, the fixed effects model ameliorates the selectivity problem. Direct tests of selectivity bias in a GLS model are provided in the following section.

B. Results

Table II gives the results for the first two of the three investment equation specifications just described. The first four columns include only long-lived firms, the last four cover all firms. Under each heading, the first three models use the broad definition of attachment, and the fourth uses the narrow definition. Though coefficients for the annual indicator variables are not reported, some of them are statistically significant—suggesting, not surprisingly, that investment has a cyclical component. The period under study, however, was generally expansionary.

The coefficient of stock liquidity in column one is insignificantly different from zero, and thus on average there is little liquidity sensitivity of investment among the long-lived firms as a group. In contrast, the coefficients of the interaction of liquidity with bank-attachment indicators are positive and significant—suggesting a strong relationship between investment and internal funds for bank-attached firms. The baseline coefficient of the Tobin's q proxy is positive and significant (in contrast to that of liquidity), yet, as evidenced by the significant negative estimates of the interaction of bank indicators with q, the corresponding coefficients for the bank-attached firms are positive but significantly lower. Together, then, the estimates indicate that unattached firms' investment responds to expected future profitability, while attached firms' investment moves with internal funds.

The results confirm the collinearity between cash flow and stock liquidity in this sample. Cash flow alone yields similar, though larger, coefficient estimates compared to stock liquidity alone. When the two variables are included together, cash flow coefficient estimates either lose all significance or reverse sign compared to specifications with cash flow alone. Table II indicates further that the results on liquidity sensitivity are robust to changes in the definition of attachment from broad (any interlock) to narrow (bank director on firm supervisory board).

Columns five through eight of Table II repeat the specifications for the full sample and include an indicator variable for membership in the IPO subsample. Coefficients of the IPO indicator variables, and the interaction of these variables with stock liquidity, suggest qualitatively similar results as those for long-lived firms taken separately.

A second set of regressions models the effects of long-term relationships between banks and firms by including an indicator variable for firms that were attached in the preceding period.[13] The long-term relationship (LTR) variable uses the broad definition of attachment and takes the value one for firms attached as of 1900 and zero otherwise. The interaction of this variable with the other exogenous variables permits a comparison between firms that were attached in 1900 as well as in 1905 and 1910 and firms that gained bank attachments after 1900 (or not at all).

Among the long-lived firms, coefficients of the interaction of these variables with liquidity are negative as expected, but they are statistically insignificant. The inclusion of the LTR variables causes little movement in the coefficient estimates of the variables from the original specification. When the IPO firms are included, the coefficients from the baseline specification are nearly unchanged. The coefficient of stock liquidity for IPO great-bank firms, however, is enormous and positive; and that on liquidity for IPO great-bank firms with long-term relationships turns nearly as large and negative. While there is some intuitive appeal to the notion that banks attach to firms with naturally tighter liquidity constraints and that they are only able to ameliorate such problems after several years of involvement, the sheer size of the coefficient estimates is suspect.

Closer inspection of the data reveals that such doubts are well-founded, since one IPO firm seems to drive the results. This firm's case underscores the potentially weak connection between liquidity sensitivity and firms' liquidity constraints. The firm in question, Rostocker Strassenbahn Aktiengesellschaft, was a light rail company operating in the city of Rostock. Having decided in 1897 to electrify the railway, the company spent six years negotiating the deal with the city.[14] In 1903, the shareholders finalized the municipal contract and voted to raise both share capital and bonds to finance the project. The firm also took a sizable loan from a large electrical firm. As a result, fixed capital rose more than threefold and revenues increased 50 percent between the close of 1903 and the close of 1904.

Through the early stages of these investment decisions, Rostocker Strassenbahn A.G. apparently had no interlocking directorates with a bank. By 1905, the firm had interlocking directorates with one of the largest universal banks, though the supervisory board member in question was not a bank director but rather a supervisory board member. Thus, the large coefficient estimates disappear under the narrow definition of bank attach-

[13] Statistical results are available from the author.

[14] The details of this case are laid out in *Saling's*, Part II (1904/5), pp. 1760–1761 and (1905/6), pp. 1605–1606.

Table II
Fixed Effects Estimates of the Investment Equation

The dependent variable, gross investment, is regressed on lagged (previous period) investment, stock of financial assets (or liquidity; SL), cash flow (CF), revenue growth, and a proxy for marginal q. The model includes interaction terms between bank attachment indicator variables and exogenous variables. Great bank, small bank, and combined banks variables indicate attachment with, respectively, the nine largest Berlin-centered joint-stock banks, any other joint-stock bank, and a combination of great and small banks. "Narrow" affiliation refers to a bank director sitting on the firm's supervisory board and "broad" affiliation refers to any interlocking of directorates between the firm and one or more banks. Annual indicator variables are included, but their coefficient estimates are omitted from the table. Level variables are normalized by base-year fixed assets. Long-lived firms operated continuously between 1880 and 1913; IPO (initial public offering) firms are those whose initial public offering came in or after 1880. Standard errors are in parentheses. An F-test of joint-significance of regressors and a Hausman chi-square test of fixed versus random effects are given at the end of the table.

	Long-Lived Firms				All Firms			
	Broad		Narrow		Broad		Narrow	
Constant	−0.25***	−0.11	−0.29***	−0.21***	−0.21***	−0.11	−0.23***	−0.14**
	(0.07)	(0.08)	(0.07)	(0.07)	(0.06)	(0.07)	(0.07)	(0.07)
Lagged investment	0.09*	0.03	0.05	0.12**	−0.01	−0.04	−0.03	0.02
	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)
Financial assets	−0.12*	—	−0.06	0.07	−0.12	—	−0.08	0.06
	(0.07)		(0.08)	(0.05)	(0.08)		(0.09)	(0.06)
Cash flow	—	−0.36	−0.28	0.01	—	−0.33	−0.25	0.00
		(0.34)	(0.34)	(0.25)		(0.34)	(0.36)	(0.27)
Revenue growth	−0.02	−0.02	−0.01	−0.00	−0.02	−0.02	−0.02	0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)
Tobin's marginal q	0.19***	0.15***	0.18***	0.11**	0.17***	0.13**	0.16**	0.08*
	(0.05)	(0.06)	(0.05)	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)
Small bank × financial assets	0.26***	—	0.38***	0.05	0.26***	—	0.36***	0.04
	(0.07)		(0.08)	(0.12)	(0.08)		(0.09)	(0.13)
Small bank × cash flow	—	0.64*	1.00***	0.48	—	0.66*	−0.79**	0.47
		(0.36)	(0.38)	(0.52)		(0.36)	(0.40)	(0.59)
Great bank × financial assets	0.28***	—	0.23**	0.22***	0.27**	—	0.21*	0.22***
	(0.10)		(0.11)	(0.06)	(0.11)		(0.11)	(0.07)
Great bank × cash flow	—	0.78	0.52	−1.35***	—	0.44	0.14	−1.32***
		(0.73)	(0.66)	(0.31)		(0.69)	(0.66)	(0.34)
Combined banks × financial assets	0.38***	—	0.33***	0.41***	0.37***	—	0.33***	0.39***
	(0.08)		(0.09)	(0.07)	(0.08)		(0.10)	(0.08)
Combined banks × cash flow	—	1.30***	0.07	−1.47**	—	1.19**	0.11	−1.45*
		(0.49)	(0.49)	(0.71)		(0.47)	(0.50)	(0.81)

Small bank × revenue growth	0.17***	0.14**	0.23***	−0.00	0.02	0.02	0.02	−0.01
	(0.05)	(0.06)	(0.05)	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)
Great bank × revenue growth	0.03	0.02	0.02	0.11	0.02	0.01	0.01	0.04
	(0.03)	(0.04)	(0.03)	(0.08)	(0.03)	(0.04)	(0.03)	(0.08)
Combined banks × revenue growth	0.01	0.04	0.01	−0.26*	−0.02	0.01	−0.02	−0.25*
	(0.07)	(0.08)	(0.07)	(0.14)	(0.06)	(0.07)	(0.06)	(0.16)
Small bank × marginal q	−0.07**	−0.05	−0.05	−0.17*	−0.07**	−0.05	−0.01	−0.12
	(0.03)	(0.04)	(0.04)	(0.09)	(0.03)	(0.04)	(0.04)	(0.10)
Great bank × marginal q	−0.11**	−0.12	−0.12	0.09*	−0.07	−0.03	−0.03	0.08
	(0.05)	(0.08)	(0.08)	(0.05)	(0.05)	(0.07)	(0.06)	(0.05)
Combined banks × marginal q	−0.15***	−0.14**	−0.14**	−0.08	−0.09**	−0.08*	−0.07	−0.02
	(0.05)	(0.06)	(0.06)	(0.10)	(0.04)	(0.05)	(0.05)	(0.11)
IPO × financial assets	—	—	—	—	−0.03	—	−0.04	−0.05
					(0.24)	(0.27)	(0.10)	
IPO × cash flow	—	—	—	—	—	0.07	0.14	0.45
						(0.89)	(0.95)	(0.38)
IPO × SL (small banks)	—	—	—	—	−0.05	—	−0.21	−0.14
					(0.23)		(0.27)	(0.87)
IPO × CF (small banks)	—	—	—	—	—	−0.14	1.07	−1.09
						(0.93)	(1.06)	(3.91)
IPO × SL (great banks)	—	—	—	—	0.40	—	3.30***	−0.20*
					(0.36)		(0.78)	(0.12)
IPO × CF (great banks)	—	—	—	—	—	0.19	−12.64***	0.65
						(1.50)	(3.11)	(0.55)
IPO × SL (combined banks)	—	—	—	—	−0.13	—	−0.16	−0.18
					(0.24)		(0.28)	(0.87)
IPO × CF (combined banks)	—	—	—	—	—	−0.56	0.15	5.24
						(0.95)	(1.04)	(7.79)
p-value (F) (Joint significance of X_j)	0.00	0.01	0.00	0.00	0.00	0.07	0.00	0.00
p-value (chi-squared) (Hausman test)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Adjusted R^2	0.25	0.10	0.32	0.37	0.19	0.07	0.25	0.26
N	478	478	478	424	619	619	619	619

*Coefficient significant at 10 percent or better (two-sided test).

**Coefficient significant at 5 percent or better (two-sided test).

***Coefficient significant at 1 percent or better (two-sided test).

ment. Since both the stock of liquid assets and cash flow were relatively small in the period preceding the surge in investment, the estimated regression line is extremely steep. These effects create what seem to be misleading results.

The case of Rostocker Strassenbahn supports the point made in Kaplan and Zingales (1997) that, in general, liquidity constraints and investment-cash flow sensitivities have no monotonic relationship to one another. In particular, this case points to certain conditions under which unconstrained firms will appear to have the greatest liquidity sensitivity. For example, long delays between the decision to invest and the beginning of investment may create the appearance of liquidity constraints even when the delays are unrelated to availability of finance. Such delays might occur in many situations and may result in the accumulation of internal funds not necessary for the investment.

While the accumulation of funds may erroneously suggest liquidity constraints, cases in which internal funds reach relatively high levels in the period before investment can actually produce lower estimates of liquidity sensitivity than situations in which internal funds or cash flow grow only moderately. Rostocker Strassenbahn, for example, did not accumulate high levels of internal funds during the years of negotiations with the city. Such behavior only supports the notion that this firm was unconstrained, since it suggests confidence that the substantial new investment could be efficiently financed through outside funds. At the same time, the rapid increase in investment, coupled with moderate growth of cash flow and liquidity, produces extremely high estimates of liquidity sensitivity.

III. The Random Effects Model with Selectivity Corrections

A causal relationship cannot necessarily be inferred from the finding that only bank-attached firms had positive liquidity sensitivity of investment. The findings heighten worries about selectivity bias, and thus this section provides a direct attempt to control for such influences. The fixed effects specification should mitigate selectivity problems because it eliminates firm-specific effects, but if biases are systematically related to characteristics other than firm identity then improvements may be possible.

It is important to realize that selectivity bias could go in either direction. If banks pursue attachment in order to facilitate ex post monitoring of investment outcomes of riskier firms, then the firms with bank attachments are likely to have a tendency toward tighter liquidity constraints. If firms pursue attachments to banks in order to signal their creditworthiness to investors, then attached firms might not be those with the greatest tendency toward financing constraints.

To control for potential selectivity bias, I use the method described by Dubin and McFadden (1984), in which a Heckman-type selectivity correction term is included as an independent variable for all but one choice category in the random effects model. The first step is to run a logit re-

gression on the multinomial choice variable for bank attachment. The errors calculated in the logit regressions are correlated with the firm-specific effects that are of concern in the investment regressions. Correction terms are then formed using the predicted probabilities from the logit estimates and are included as exogenous variables in the investment regressions. The coefficients of these selectivity terms measure the correlations between unobserved firm effects and unobserved factors that influence the probability of attachment.

Table III presents the results of the random effects procedure, and the four columns correspond to those in Table II. The selectivity correction terms are statistically significant in only about one-third of the cases. Among long-lived firms, the combined-bank firms show a significant, negative a priori effect on investment, while great-bank-only firms exhibit a positive, and only weak, relationship. The results for the great-bank and combined-bank firms are essentially reversed in the IPO sample, though the negative coefficients of the great-bank-only correction term are substantially larger in absolute value than any of the other coefficients. This effect is likely due to the same outlier discussed previously. In both subsamples, it is the category that contains the largest firms that obtains negative coefficients of the corrections term.

Overall, the random effects models suggest that selectivity bias plays only a limited role in the findings on liquidity sensitivity. Among long-lived firms, the biggest effect on the coefficient estimates for liquidity derives from the change to the random effects model. Exclusion of the selectivity correction terms produces almost no effect on the coefficient estimates or robustness tests. Indeed, the coefficients of liquidity for all categories of bank attachment are actually higher when the corrections terms are included. This suggests that, if anything, the selectivity bias causes underestimation of liquidity sensitivity for attached firms.

The correction terms wield considerable statistical influence among the IPO firms. The exclusion of these terms yields more extreme estimates of liquidity sensitivity—in the positive direction for great-bank firms overall and in the negative direction for great-bank firms with long-term relationships. Though this suggests that selectivity bias accounts for part of the extreme values of liquidity sensitivity of great-bank firms, the majority of the effect can still be attributed to the one outlier firm-year described in the previous section. In the absence of this outlier, the regression results for the IPO firms alone are statistically insignificant. Clearly, part of the poor statistical performance of the IPO subsample taken alone stems from the small number of observations. This is a problem that can only be addressed through expansion of the sample.

The power of the GLS-selectivity correction model hinges on the proper specification of the discrete choice model in the first step. To the extent that the first step fails to capture the effects of group selection bias, the random effects model may retain selection bias.

The dependent variable in the logit equation is the four-choice attachment variable. The independent variables include the variables involved in the investment equation—investment, stock liquidity, revenue growth, and Tobin's

Table III

Random Effects Estimates of the Investment Equation

The dependent variable, gross investment, is regressed on selection bias correction terms, lagged (previous period) investment, stock of financial assets (or liquidity; SL), cash flow (CF), revenue growth, and a proxy for marginal q. The model includes interaction terms between bank attachment indicator variables and exogenous variables. Great bank, small bank, and combined banks variables indicate attachment with, respectively, the nine largest Berlin-centered joint-stock banks, any other joint-stock bank, and a combination of great and small banks. "Narrow" affiliation refers to a bank director sitting on the firm's supervisory board and "broad" affiliation refers to any interlocking of directorates between the firm and one or more bank. Annual indicator variables are included, but their coefficient estimates are omitted from the table. LTR (long-term relationship) indicates bank affiliation existed three years prior to the start date of the current sample. The correction terms control for the correlation between unobserved firm effects and unobserved factors that influence the probability of bank affiliation. Level variables are normalized by base year fixed assets. Long-lived firms operated continuously between 1880 and 1913; IPO (initial public offering) firms are those whose initial public offering came in or after 1880. Standard errors are in parentheses. The p-values of a chi-squared test of joint-significance of regressors and a Hausman chi-square test of fixed versus random effects are given at the end of the table.

	Long-Lived Firms		IPO Firms	
Constant	0.03	−0.04	0.02	−0.35
	(0.06)	(0.06)	(0.58)	(0.70)
Selection bias correction term	−0.02	−0.01	0.02	0.03
(small banks)	(0.02)	(0.02)	(0.07)	(0.06)
Selection bias correction term	0.02	0.04	−0.54***	−0.27***
(great banks)	(0.02)	(0.02)	(0.10)	(0.09)
Selection bias correction term	−0.05***	−0.06***	0.09	0.07
(combined banks)	(0.02)	(0.02)	(0.06)	(0.05)
Lagged investment	0.05	0.04	−0.09	0.01
	(0.05)	(0.05)	(0.09)	(0.07)
Financial assets	−0.04	−0.05	−0.22	−0.02
	(0.04)	(0.04)	(0.19)	(0.17)
Revenue growth	−0.01	−0.01	−0.18***	−0.12**
	(0.02)	(0.02)	(0.06)	(0.06)
Tobin's marginal q	0.01	0.02	−0.37	0.15
	(0.03)	(0.03)	(0.40)	(0.57)
Small bank	0.08	0.07	−0.07	0.33
	(0.08)	(0.08)	(0.64)	(0.77)
Great bank	−0.03	−0.08	0.43	0.44
	(0.11)	(0.11)	(0.66)	(0.74)
Combined banks	0.14*	0.11	−0.13	0.10
	(0.07)	(0.07)	(0.61)	(0.72)
Small bank × stock liquidity	0.07**	0.08*	0.22	0.04
	(0.04)	(0.04)	(0.18)	(0.19)
Great bank × stock liquidity	0.13**	0.15**	−0.33	9.20***
	(0.07)	(0.07)	(0.27)	(1.08)
Combined banks × stock liquidity	0.12***	0.23***	0.23	0.09
	(0.04)	(0.05)	(0.18)	(0.18)
Small bank × revenue growth	0.14***	0.14***	0.18***	0.12
	(0.05)	(0.05)	(0.06)	(0.06)
Great bank × revenue growth	0.01	0.02	−0.14	0.00
	(0.03)	(0.03)	(0.10)	(0.09)

Table III—*Continued*

	Long-Lived Firms		IPO Firms	
Combined banks × revenue growth	0.03	0.04	0.12	0.06
	(0.07)	(0.07)	(0.17)	(0.14)
Small bank × marginal q	−0.01	−0.02	0.44	−0.20
	(0.03)	(0.04)	(0.41)	(0.58)
Great bank × marginal q	−0.02	−0.01	1.17***	−0.06
	(0.04)	(0.05)	(0.48)	(0.60)
Combined banks × marginal q	−0.04	−0.04	0.41	−0.10
	(0.04)	(0.04)	(0.40)	(0.57)
LTR	—	0.01	—	0.11**
		(0.03)		(0.05)
LTR × liquid assets	—	−0.22	—	−3.20
		(0.22)		(2.97)
LTR × liquid assets (small banks)	—	0.16	—	3.16
		(0.22)		(2.97)
LTR × liquid assets (great banks)	—	0.16	—	−5.74*
		(0.23)		(3.15)
LTR × liquid assets (combined banks)	—	0.10	—	3.12
		(0.22)		(2.96)
p(chi-square) [joint significance of X_j]	0.00	0.00	0.00	0.00
p(chi-squared) [fixed vs. random effects]	0.00	0.00	0.00	0.84
Adjusted R^2	0.14	0.18	0.29	0.62
N	478	478	141	141

*Coefficient significant at 10 percent or better (two-sided test).
**Coefficient significant at 5 percent or better (two-sided test).
***Coefficient significant at 1 percent or better (two-sided test).

marginal q—as well as a vector of exogenous control variables—fixed assets (to measure size), age, capital intensity (the ratio of fixed capital to revenues), leverage (the ratio of outside to inside finance), profit margin (the ratio of profits to revenues), and dividends (in the case of long-lived firms).[15] Table IV gives the results of this procedure. The first three columns of Table IV cover the long-lived firms, while the last three cover the IPO firms. Within each subsample, the columns give the results for each attachment category.

Perhaps the most notable result is that neither investment nor revenue growth predicts bank affiliation. These two variables measure the rate of growth of a firm, and by either metric rapid growth provides no indication of bank affiliation. Among long-lived firms, normalized stock liquidity positively predicts bank attachment, but for IPO firms, liquidity positively predicts only small-bank affiliation.[16]

[15] The capital intensity variable proxies for the capital-output ratio and uses revenues in the denominator due to the lack of output data.

[16] Much of the magnitude and statistical significance of the coefficient of great-bank liquidity is derived from the outlier firm discussed in the previous section. When that firm is dropped from the sample, the coefficient rises to negative two, and the p-value of the t-statistic falls to 17 percent.

Table IV

Logit Estimates: Firm Characteristics Associated with Bank Attachment

The dependent variable—a discrete attachment-choice variable—takes the values zero through three for interlocking directorates with no bank, small bank, great bank, and a combination of banks, respectively. Great banks consist of the nine largest Berlin-centered joint-stock banks, small banks are all others, and combination refers to a mix of great and small banks. Long-lived firms operated continuously between 1880 and 1913; IPO (initial public offering) firms are those whose initial public offering came in or after 1880. Standard errors are in parentheses. Investment and liquidity are normalized by fixed assets. Annual indicator variables are included as exogenous variables, but their coefficient estimates are omitted from the table. The p-value for a chi-squared test of joint-significance of regressors is given at the end of the table. Standard errors are in parentheses.

	Long-Lived Firms			IPO Firms		
Independent Variables	Small Bank vs. No Bank	Great Bank vs. No Bank	Combination vs. No Bank	Small Bank vs. No Bank	Great Bank vs. No Bank	Combination vs. No Bank
Constant	−4.69***	−7.19***	−2.87**	−3.37*	−2.94	−3.00
	(1.08)	(1.42)	(1.17)	(1.96)	(2.44)	(1.98)
Investment	0.56	−0.03	1.04	2.28	4.28	3.05
	(0.95)	(1.37)	(0.99)	(4.25)	(4.54)	(4.50)
Financial assets	0.86***	0.64*	0.66**	0.40**	−3.22**	−0.10
	(0.29)	(0.36)	(0.30)	(0.21)	(1.45)	(0.24)
Revenue growth	−0.49	0.31	−0.31	0.02	−0.56	−1.04
	(0.39)	(0.21)	(0.47)	(0.06)	(1.76)	(0.96)
Tobin's marginal q	0.15	2.46***	0.93*	1.67	2.74	4.09***
	(0.46)	(0.58)	(0.50)	(1.51)	(1.74)	(1.47)
Fixed assets	−0.09**	0.01	0.15***	0.04	0.38**	0.24
	(0.04)	(0.04)	(0.03)	(0.16)	(0.16)	(0.16)
Age	0.14***	0.10***	0.03	0.03	0.02	−0.14**
	(0.03)	(0.04)	(0.03)	(0.07)	(0.08)	(0.07)
Capital intensity	0.01	0.15***	−0.07	0.08	0.41*	−0.03*
	(0.03)	(0.03)	(0.07)	(0.07)	(0.21)	(0.07)
Leverage	−0.01	−0.02***	−0.01	0.01*	0.01	−0.01
	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
Profit margin	0.50	2.62***	3.25***	0.09	−0.78	−0.05
	(0.53)	(0.53)	(0.80)	(1.29)	(3.32)	(1.53)
Dividends	−0.04	−0.42***	−0.19**	—	—	—
	(0.07)	(0.09)	(0.08)			
p-value of (chi-square)	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.33	0.33	0.33	0.44	0.44	0.44
N	478	478	478	141	141	141

*Coefficient significant at 10 percent or better (two-sided test).

**Coefficient significant at 5 percent or better (two-sided test).

***Coefficient significant at 1 percent or better (two-sided test).

Age, size, and common-equity q also appear as strong indicators of bank attachment. In contrast, debt-equity ratios and capital intensity provide less information about bank attachment than might be expected. Neither variable offers consistently positive predictions of attachment. Profit margins strongly predict bank attachment among long-lived firms with great-bank attachment, with or without additional connections. IPO firms with similar connections did not experience similarly high margins, so it is safe to say

that bank-attachment is not uniformly associated with high profitability. Such findings lend support to the notion that banks and firms formed relationships for a variety of reasons.

Despite the positive predictions of profitability for long-lived, great-bank firms, dividends negatively predict attachment. Given the high rates of internal liquidity for bank-attached firms, these findings suggest that affiliated firms retained a relatively high share of their profits to hold in the form of financial assets rather than distributing dividends. Without knowing the results of the investment regressions, this would seem to be a surprising result because it suggests that bank-attached firms were subject to greater liquidity constraints than were unattached firms. Indeed, Fazzari et al. (1988) use low dividend payouts as their indicator of liquidity constraints.

Using a specification similar to that used in Fazzari et al. (1988), the current data yield a coefficient of baseline stock liquidity that is positive (0.32) and strongly significant, while that of liquidity for high-dividend firms is significantly lower (0.13). The overall significance and explanatory power of the regression are approximately the same as in the bank-sorted specifications. Since bank-attached firms are no more likely to fall into the low-dividend category, dividend sorting is not equivalent to bank-attachment sorting. The fact that the current data replicate the Fazzari et al. (1988) results lends further credence to the other econometric results reported in this paper.

IV. Concluding Remarks

This paper offers several insights into the question of relationship banking and industrial investment. The results suggest that the German universal banks neither promoted high levels of investment nor produced large, static effects on firms' liquidity sensitivity during the period of rapid economic growth before World War I. Bank relationships may have provided partial attenuation of firms' liquidity sensitivity of investment over time in some cases, but the evidence on this count is weak. These conclusions are hardly those that would be expected, given the abundant qualitative literature on universal banks and their beneficial influence on firm growth during the German industrialization.

The findings also shed light on more general questions of the importance of relationship formation on the part of financial intermediaries. The results undermine widely held beliefs about the benefits of universal banking and also contradict the findings of several recent papers. Previous work on banking relationships and firm liquidity sensitivity largely neglect the process of attachment. The logit analysis and selectivity-corrected GLS models in this paper represent a first step in explicitly modeling the determinants and effects of bank affiliation decisions.

The evidence in this paper is of particular interest in light of recent debates about the usefulness of investment-cash flow sensitivities in measuring liquidity constraints. The analysis shows that the existence of high liquidity sensitivity provides an inconsistent measure of liquidity constraints and therefore

offers support for some of the contentions in Kaplan and Zingales (1997). While the results for the long-lived firms appear to be free of outlier influence, the findings of extremely high liquidity sensitivity among great-bank attached, IPO firms clearly stem in large part from the influence of one firm. Closer investigation shows that this firm suffered from no apparent liquidity constraints, yet it had radically higher estimated liquidity sensitivity than other firms. These findings warn of the potential for misleading conclusions when liquidity sensitivity is assumed to measure liquidity constraints. Further investigation into this area is necessary, and the use of case studies and qualitative evidence represents a potentially fruitful avenue for such research.

At a minimum, the current results demonstrate that the effects of bank attachment on firms' liquidity sensitivity are not generalizable and suggest that there is good reason to question the ability of relationship banking to produce dramatic results. The fact that empirical findings differ depending on context complicates attempts to draw lessons for banking regulation. Until the potential costs are fully understood, however, caution should be recommended in drawing policy conclusions in favor of intensifying formal relationships between banks and the firms they finance.

Appendix

The selectivity correction terms are derived according to Dubin and McFadden (1984). The expected value of the disturbance conditional on a particular choice I having been made is

$$E(\eta|I) = \sum_{j\neq I}^{m}\left[\frac{\sigma\sqrt{6}R_j}{\pi}\right]\left[\frac{P_j \ln P_j}{1-P_j} + \ln P_i\right] \tag{A1}$$

where R_j is the correlation between η and ϵ_j, m is the number of mutually exclusive and exhaustive choice alternatives, p_j is the multinomial logit estimate of the probability of choosing category j versus the base category, and δ_j is an indicator variable that takes the value one if an individual chooses category j and zero otherwise. It follows that

$$\sum_{I=1}^{m} E[\eta|I]\delta_i = \sum_{j=2}^{m}\left[\frac{\sigma\sqrt{6}R_j}{\pi}\right]\left[\frac{(P_j-\delta_j)\ln P_j}{1-P_j} - \frac{(P_1-\delta_1)\ln P_1}{1-P_1}\right] = \sum_{j=2}^{m} Q_j H_j \tag{A2}$$

and H_j is the correction term. In the m-choice case, there will be $m-1$ such terms of the form

$$H_j = \left[\frac{(p_j-\delta_j)\ln p_j}{1-p_j} - \frac{(p_1-\delta_1)\ln p_1}{1-p_1}\right] \tag{A3}$$

for $j = 2,3,\ldots,m$.

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