Delivering Deposit Services: ATMs Versus Branches

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Over the past 20 years (1973–1992), the total number of banking offices has grown from 40,600 to 63,900, an expansion of 57 percent. This exceeded the 21 percent growth in the adult (age 18 and older) population. The number of automated teller machines (ATMs) has grown even more rapidly, from fewer than 2,000 to more than 90,000 over the same period. As a total, there was one banking office or ATM for 3,700 people in 1973. In 1992, there were three banking offices or ATMs for the same number of people. This increase effectively tripled the accessibility and convenience of bank-provided deposit services. In addition, ATMs are typically "open" 24 hours a day, providing even more convenience than a traditional banking office.

Ever since ATMs were first introduced in 1971, they have been touted as a potentially lower-cost alternative to the traditional branch banking office. The presumption of cost savings from expanded ATM use has in the past focused on scale economies. Substantial scale economies were indeed estimated for ATMs using special FDIC survey data for 1975 (Walker 1978, 1980). This early analysis is augmented here with a new estimate of ATM scale economies using survey data for 1984. The two scale estimates are similar but suggest that ATM technology has improved over time, leading to greater scale economies.

While ATM scale economies appear to be substantial, they may not translate into reductions in bank costs or increases in bank profits. This can occur if, for the same set of "free" or below-cost deposit services, consumers use ATMs more intensively than they had previously used a traditional banking office. Similarly, the scale economy benefits of ATMs can be dissipated if ATMs are

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"oversupplied" to consumers primarily to enhance or maintain deposit market shares. Thus the existence of ATM scale economies may or may not lead to lower bank costs or increases in profits.

The primary purpose of this article is to determine the impact of an increase in ATM use on bank costs and profits. This is obtained by estimating separate multi-output banking cost and profit functions using cross-section data for 161 banks during 1991 and 1992. In brief, there appears to be no significant reduction in costs when ATMs are substituted for banking offices in the delivery of deposit services. On balance, while consumers have clearly benefited from the increased availability and convenience of an expansion of banking offices and ATMs over the last 20 years, banks today realize no net cost savings from these developments. Indeed, deposit delivery costs are higher, not lower. However, because of revenue effects, net income (profit) is marginally higher and represents a small net benefit to banks.

1. ATM USE, SCALE ECONOMIES, AND TRANSACTION COST

The Structure of U.S. Payments

Table 1 shows the percentage volume and values of the various methods of making payments in the U.S. economy. As in most countries, cash is the most frequently used payment instrument. Cash is estimated to account for 83 percent of all U.S. payment transactions.[1] The next most important instrument in terms of transaction volume is the check at 14 percent. Thus cash and checks account for over 97 percent of transaction *volume*. All other payment instruments—credit cards, automated clearing house (ACH) "electronic checks," traveler's checks, money orders, point of sale (POS) debit cards, and wire transfers—account for less than 3 percent of total transactions. The ordering for transaction *value* is a different story. Wire transfers, which average $3.3 million per transaction, account for 82 percent of total payment value, while checks comprise 16 percent. Thus over 98 percent of payment values are shouldered by wire transfers and checks. The value of cash transactions is less than one-half of 1 percent of the total.

While surveys show that cash is the most frequently used payment method, the overall value of cash transactions is small because cash is used primarily for small-value transactions. ATMs fit into the U.S. payment structure in two

[1] Cash has been estimated to account for 86 percent of all payment transactions in Germany, 78 percent in the Netherlands, and 90 percent in the United Kingdom (Boeschoten 1992, pp. 73–74). The procedures used to estimate U.S. payment volumes and values are quite complex and are contained in Humphrey and Berger (1990), Table 2-A1.

Table 1 The Structure of the U.S. Payment System

Type of Payment Instrument	Volume Composition (percent)	Value Composition (percent)	Average Value (dollars)
Nonelectronic			
Cash	83.4	0.4	5
Check	14.1	16.3	1,188
Electronic			
Credit Card	2.1	0.1	62
ACH	0.3	1.1	3,882
Wire Transfer	0.1	82.1	3,300,000

Source: Humphrey and Berger (1990), Table 2-A1.

ways. First, ATMs are an increasingly important source of cash to deposit holders for cash transactions. Second, the greater convenience of ATMs has lowered the transactions cost of using cash as a means of payment (Boeschoten 1992; Daniels and Murphy 1993).

Prior to the 1940s, most cash was obtained at the workplace; employees were commonly paid in cash, usually on a weekly basis. After employers converted to payroll checks, the main sources of cash acquisition shifted to cashing one's entire paycheck, writing checks for cash at one's bank, or writing a check at the supermarket or other retail establishment for a value larger than the purchase amount. Now, with easy access to ATMs, cash is substituting for checks written solely to obtain cash—previously 8 percent of all checks (Bank Administration Institute 1979).

What Do ATMs Do?

ATMs provide many of the most demanded deposit services. In order of importance, as shown in Table 2, these services include cash withdrawals, cash or check deposits, transfers among deposit accounts, and bill payments.[2] Surveys suggest that cash withdrawal accounted for 77 percent or more of all ATM transactions in 1991, 1984, and 1975. Since only 1 percent of ATM transactions represent bill payments, it would be incorrect to conclude (as some have) that ATMs represent a move to electronic payments. In fact, ATMs have promoted an increased use of cash to the detriment of checks and potential electronic

[2] Since separate balance inquiry transactions are commonly made prior to withdrawing cash to see if the balance is sufficient for the withdrawal, these transactions have not been included in the breakdown in Table 2.

Table 2 Use of ATM Services

	1975	1984	1991
Cash Withdrawal	77%	77%	86%
Cash or Check Deposit	20	19	10
Account Transfer	2	3	3
Bill Payment	1	1	1

Source: Walker (1978); van der Velde (1985); and Board of Governors of the Federal Reserve System (1991).

payments such as point of sale (POS) debit cards. Furthermore, ATMs are also a partial substitute for nationwide bank branching because they enable depositors to obtain cash from their deposit account while traveling out of state.

ATM Scale Economies

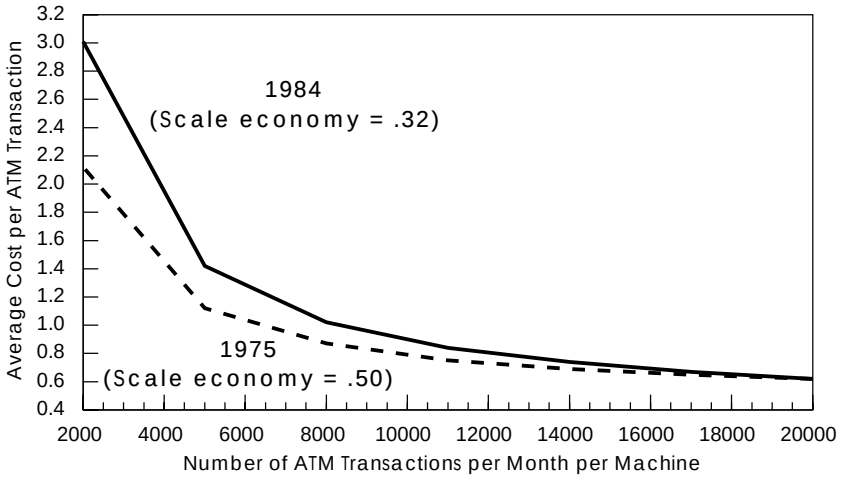
Because of scale economies, the early promise of ATMs was that the cost of an ATM transaction at mature volumes would be considerably below the cost of the same transaction at a standard branch office. Early analysis by Walker (1978) found large scale economies associated with increases in ATM transaction volume. Scale economies for 1975 are illustrated by the dashed line in Figure 1. In this year, the average total cost per ATM transaction rises only by 5 percent for each 10 percent increase in total monthly transactions volume, giving a scale economy measure of .50.[3] The solid line in Figure 1 shows ATM scale economies for 1984. There is some improvement because the cost per transaction is estimated to rise by only 3.2 percent for each 10 percent increase in transaction volume, giving a scale measure of .32.[4]

At a monthly transaction volume close to 5,000, Walker found that the cost per ATM transaction was substantially less than that of a transaction in a traditional banking office. By 1992, average transaction volume per ATM per month was over 6,000 (Barthel 1993a). Therefore, if Walker's analysis was correct, scale economies are being realized and ATM costs per transaction should be less than at a traditional banking office. A later detailed study by

[3] The scale economy value of .50 was derived from a simple log-linear equation relating ATM total costs to ATM transactions (Walker 1978).

[4] The scale economy value of .32 is derived from an in-depth cost analysis (van der Velde 1985, Figures 2 and 4) that gave $.36 as the mean average variable cost per ATM transaction (assumed to remain constant) and $1.22 as the mean average fixed cost per ATM transaction (which will fall as volume is raised above the mean). These values were determined at a monthly mean per machine transaction volume of 4,343. From these data, the implied total cost associated with different ATM transaction volumes was constructed and used in ln (total cost) $= a + b$ ln (transaction volume); estimation gave $b = .32$—the constant scale elasticity.

Figure 1 Relationship Between the Average Cost and Volume of ATM Transactions



Note: Computed from Walker (1978) and van der Velde (1985); see footnote 4 in the text.

Berger (1985) supported this conclusion and found that the fully allocated cost of a cash withdrawal transaction using an ATM was about one-half the cost of the same transaction using a human teller in a bank branch office. These studies therefore support the early historical presumption for cost savings by substituting ATMs for banking offices.

Lower ATM Cost per Transaction Offset by Higher Usage

While it is thus clear that the average transaction cost of an ATM is considerably below the cost of using a standard banking office, this lower unit cost has not translated into much overall cost savings for banks. The problem has been that the greater convenience of ATMs has led users to withdraw less cash per transaction from ATMs than they did from a branch office. This response is consistent with the inventory theory of demand for idle cash balances (Baumol 1952). The greater convenience of ATMs reduced the cash acquisition transaction cost for depositors, leading to a greater frequency of these transactions and a corresponding reduction in the average amount of idle cash balances held by the public.[5]

[5] Reductions in average idle cash balances may occur even if there is increased use of cash in payment transactions, as noted above. Although the reduction in idle cash balances likely has affected the monetary aggregates, this influence was in all probability smaller than two other important events—the rise in cash management and money market mutual funds—that occurred at the same time.

Although an ATM transaction costs as little as one-half as much as a teller transaction at a branch, ATMs are being used up to twice as often as was a teller. As a result, the cost savings per ATM transaction expected by banks has been largely offset by the unexpected increase in use (Berger 1985).

Until recently, about the only way most banks have obtained revenues on their ATM investment has been through fees charged when one bank's ATM is used by a customer of another bank.[6] When a customer uses another bank's ATM—a "foreign ATM"—for cash withdrawal, an interchange fee of about $1.00 is commonly assessed. In contrast, a cash withdrawal from an ATM owned by one's own bank is usually, but not always, free.[7] Although the foreign ATM fee may seem relatively small, it generates the majority of revenues associated with ATM use. As ATMs have expanded, the number of foreign (cash withdrawal, etc.) transactions has risen from 15 percent of all transactions in the mid-1980s, to 40 percent in 1989, to around 50 percent today (McAndrews 1991).

2. GROWTH IN ATMS OVER TIME

Availability of ATMs: 1973–1992

An estimate of the total number of ATMs in the United States is shown by the solid line in Figure 2.[8] When first introduced in 1971, ATMs expanded at an increasing rate until 1984–85, at which point the yearly expansion fell off markedly as the market became increasingly saturated. This pattern of growth—increasing at an increasing rate, reaching an inflection point, and then growing at a decreasing rate—is standard for new innovations.

Have ATMs Replaced Bank Branches?

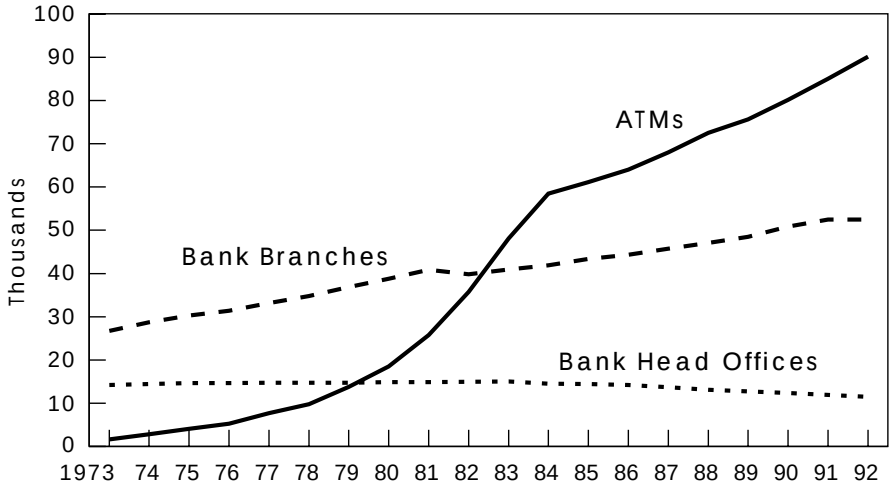
Since ATMs represent an alternative delivery method for deposit services, their rapid expansion suggests that they may have substituted for the traditional banking office in providing deposit services to the public. The growth in banking offices is also shown in Figure 2 and is divided between head offices (dotted

[6] In some cases, banks have provided ATMs not because of a strong expectation of reducing costs but rather as a defensive measure to preserve deposit market share as competitors introduced this new service for their customers.

[7] Only about one-fourth of banks charge their own customers for using the bank's own ATMs. This fee was about $.40 per transaction in 1992 (Barthel 1993a). The $1 fee for use of a foreign ATM is cost-effective, compared to a traveler's check, if more than $100 is withdrawn. Traveler's checks typically carry a fee of 1 percent of the dollar value obtained.

[8] Eugene Snyder of the Division of Federal Reserve Bank Operations at the Federal Reserve Board in Washington, D.C., provided these estimates based on industry benchmark figures and interpolation for years with missing values. These estimates are very similar to those of Laderman (1990) who obtained her primary estimates from the same source—*Bank Network News*.

Figure 2 Number of ATMs, Bank Branches, and Head Offices

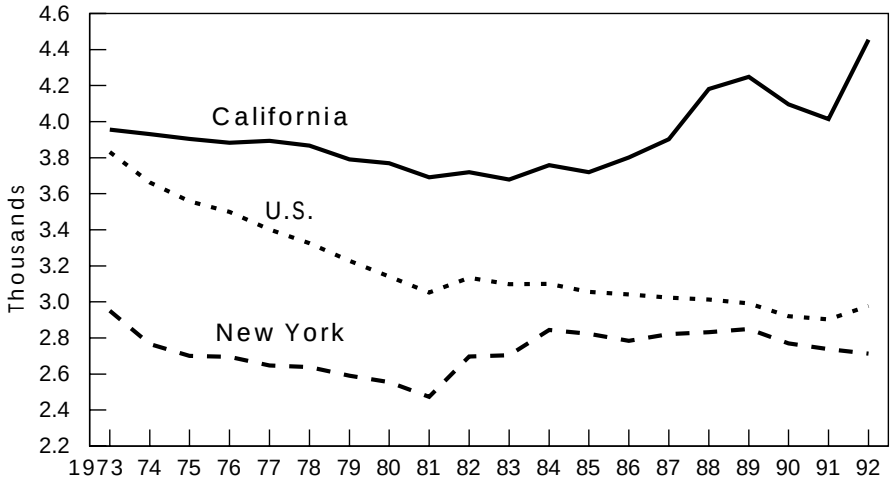


Source: FDIC, *Statistics in Banking*, various issues, and Eugene Snyder, Federal Reserve Board, Washington, D.C. (estimates of ATMs).

line) and branches (dashed line). The main point of this comparison is the more rapid growth of ATMs. While there were fewer than 2,000 ATMs and 26,700 branches in 1973, there were 90,000 ATMs and 52,400 branches in 1992. Over this same time period, the number of head offices—which equals the number of banks—fell slightly from 14,200 to 11,500. It is estimated that in 1993 around 40 percent of depositor transactions at financial institutions will be performed by ATMs rather than by tellers at branch offices (Barthel 1993b). In addition, consultant analysis suggests that by the end of the decade the number of branch offices could fall by 20 percent as bank customers are increasingly directed toward self-service activities (Tracey 1993).

One crude measure of banking office convenience would be the population served per banking office (specifically, the number of individuals 18 years and older per branch plus head office). This relationship is shown for the entire country by the dotted line in Figure 3. There is a downward trend in the number of individuals per banking office, falling from 3,800 per office in 1973 to 3,000 per office in 1992. Thus banking offices expanded more rapidly than the population being served. If ATMs replaced banking offices, we might have expected that the population/office ratio would have risen, not fallen as the aggregate data in Figure 3 indicates.

Figure 3 Population Served per Banking Office



Source: FDIC, *Statistics in Banking*, various issues, and U.S. population data on individuals age 18 and older.

The aggregate U.S. data, however, is biased by the fact that over the 1973–1992 period, 13 states removed restrictions on intra-state branching (Amel 1993). By 1992 all states allowed limited or statewide branching. The removal of branching or "unit banking" restrictions in various states has in the past led to increases in the number of banking offices in these states (Savage and Humphrey 1979). Thus the aggregate population/office ratio would fall for this reason alone.

Two large states, California (solid line) and New York (dashed line), however, had no restrictions on intra-state branching during the 1973–1992 period. These two states account for 28 percent of total domestic deposits and are the home states of the largest banks in the United States. In both states the population/office ratio first fell and then rose over 1973–1992. This result is consistent with ATMs substituting for offices after the early 1980s when the growth in offices did not keep pace with the growth in population in these two states. Anecdotal information also suggests that the increased focus on reducing bank operating costs after the early 1980s, along with the opportunity given management through mergers of banks in overlapping market areas to close underutilized branch offices and rely instead on ATMs, facilitated a substitution of ATMs for banking offices and personnel (Barthel 1992).

3. ARE ATMS ASSOCIATED WITH HIGHER OFFICE PRODUCTIVITY, LOWER AVERAGE COST, OR HIGHER AVERAGE PROFITS?

The Core Deposit/Office Ratio and ATM Use

A simple but approximate measure of the "productivity" of a bank's branch office network commonly used in the banking industry is the core deposit/office ratio. The value of core deposits—demand, savings and small-denomination time deposits—represents an important banking "output," while the number of banking offices reflects an important banking "input." Indeed, the production of deposit services accounted for 49 percent of all bank value added during the 1980s, as measured by the allocated costs for physical capital, labor, materials, and other noninterest expenses, while loans accounted for only 28 percent.[9] The question addressed here is how this simple "productivity" measure—output per unit of input—varies with increases in ATM use.

Figure 4 shows a plot and the fitted regression line of the relationship between the log of the core deposit/office ratio and the intensity of ATM use, as reflected in the log of the ATM/office ratio.[10] For all of the 161 banks sampled both in 1991 and 1992, there is a positive (and statistically significant) relationship; that is, the simple productivity measure rises as the intensity of ATM use increases.[11]

The positive relationship shown is consistent with the contention that increases in ATM use allow the number of branches to decline while supporting the same level of deposit services. Based on the regression results, a 300 percent increase in the intensity of ATM use—moving from one ATM for every two banking offices to two ATMs per banking office—is associated with a 120 percent increase in deposits, from $20 million to $44 million per average office.[12]

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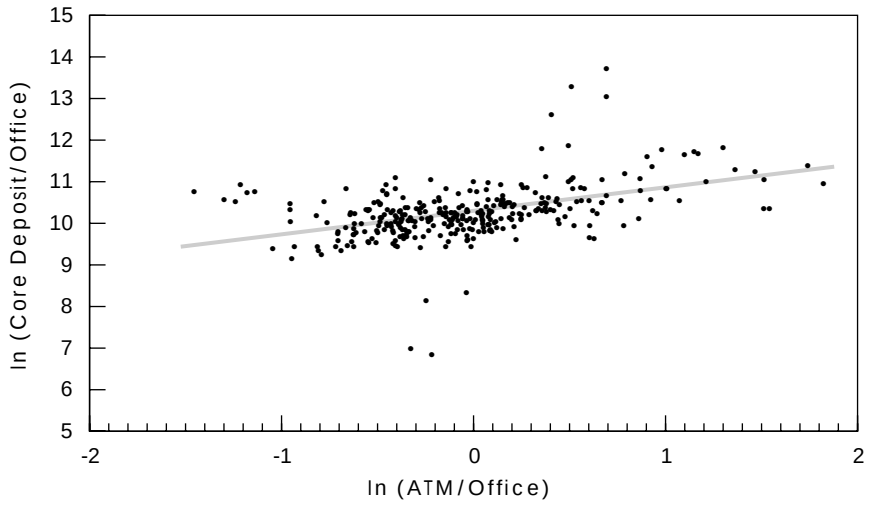
[9] These cost allocations are from the Federal Reserve's survey of financial institutions reported annually in *Functional Cost Analysis* and refer to banks with $200 million to $1 billion in deposits.

[10] The relationship shown and fitted is the following: ln (core deposit/office) $= 10.30 + .56$ ln (ATM/office). Both estimated parameters were significantly different from zero at the .05 level; the adjusted $R^2 = .20$. The double log specification was used to reduce the possible effects of heteroscedasticity as the variance of the dependent variable appeared to become larger for greater values of the independent variable. A quadratic specification gave similar results.

[11] Strictly speaking, we would expect banking output to rise if we increase inputs, such as increasing the use of ATMs. Thus our focus is on how much this single factor productivity measure rises, rather than if it rises at all.

[12] Referring to footnote 10, when ATM/office $= .5$, the predicted core deposit/office ratio is $\exp[10.30 + .56(\ln .5)] =$ $20 million. When ATM/office $= 2$, the predicted core deposit/office ratio is $\exp[10.30 + .56(\ln 2)] =$ $44 million.

Figure 4 Relationship Between Core Deposit/Office and ATM/Office Ratios, 1991–1992



Source: See the appendix.

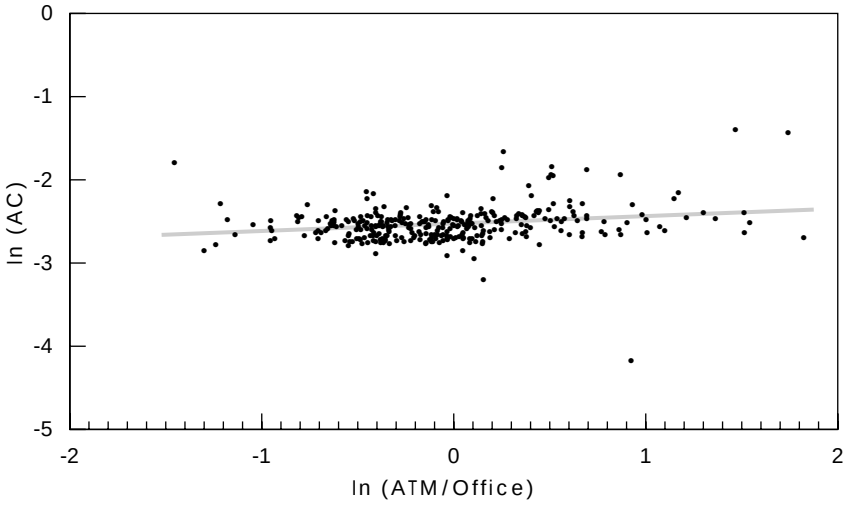
Average Cost and ATM Use

Since deposits are generally a cheaper source of loanable funds than purchased money, the result that the core deposit/branch ratio seems to rise with more intensive use of ATMs may also translate into a lower average cost of banking activity as the intensity of ATM use increases. The average cost (AC) of banking activity is measured here as the total operating plus interest cost per dollar of assets, or the total cost/total asset ratio.

Figure 5 shows how the measure of average cost varies with the ATM/office ratio for the same set of banks. The fitted relationship is slightly positive, suggesting that greater intensity of ATM use may be associated with a higher total cost/total asset ratio. The estimated relationship is exceedingly weak, however, since ATMs are only a small component of total cost. Although we do not rely on these estimates, due to a very low R^2, they weakly suggest that average cost may rise by 13 percent with a 300 percent increase in ATM intensity—from 7.56 cents per dollar of assets with one ATM for every two offices to 8.56 cents with two ATMs per office.[13]

[13] The estimated relationship is $\ln(AC) = -2.52 + .09\ \ln(ATM/office)$ and both parameters are significant at the .05 level. However, the adjusted R^2 is only .05. The predicted values of AC associated with ATM use are derived from $\exp[-2.56 + .09 \ln(ATM/office)]$, where ATM/office ranges from .5 to 2 (as in the previous footnote). A quadratic specification yields similar results. When operating cost per dollar of assets was used as the dependent variable, average operating cost also rose with the increase in the ATM/office ratio (not shown).

Figure 5 Relationship Between Average Cost (AC) and ATM/Office Ratios, 1991–1992



Source: See the appendix.

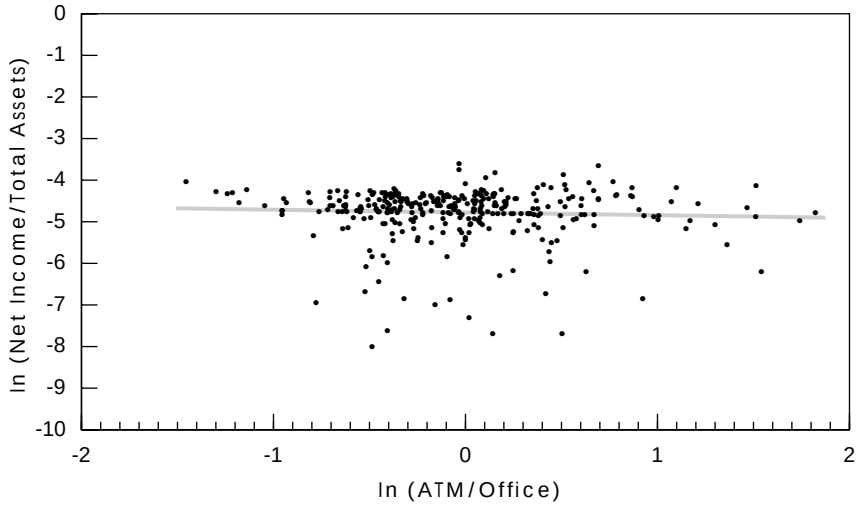
Average Profits and ATM Use

Although average costs do not appear to fall as ATMs are more intensively used, it is possible that bank revenues may be higher when more ATMs are provided. First, revenues are generated directly when a foreign ATM is used. In addition, about one-fourth of banks charge their own customers for using the bank's own ATMs. Second, the expanded convenience of ATMs may enable a bank to retain a more profitable customer base than would otherwise be possible. This may raise revenues from non-deposit services and/or permit a bank to pay a lower deposit interest rate or assess a higher monthly minimum balance on deposit accounts. All of these influences, if they are significant, could lead to higher bank profits.

Figure 6 shows a plot and the fitted relationship between the log of the ratio of net income (a common measure of bank profits) to total assets and the log of the ATM/office ratio.[14] As shown, it appears that bank profits—here measured by the return on assets (ROA)—fall slightly as the intensity of ATM use rises. However, this reduction in ROA is not significant (and the $R^2 = .00$).

[14] The relationship is the following: ln(net income/total assets) $= -4.78 - .06$ ln(ATM/office). Only the intercept was significantly different from zero at the .05 level. The same results were obtained from a quadratic specification.

Figure 6 Relationship Between Return on Assets and ATM/Office Ratios, 1991–1992



Source: See the appendix.

Therefore, ROA is apparently not affected by a 300 percent increase in ATM intensity—from one ATM for every two offices to two ATMs per office.

From this simple analysis, it appears that while there is an improvement in the core deposit/office ratio with increases in ATMs, average costs do not appear to fall. In addition, profits—as measured by ROA—are neither reduced or increased as ATMs are substituted for traditional branch offices in the delivery of deposit services. However, the analysis presented does not control for the many other factors that are known to influence bank costs and profits. To address this issue, and also to provide a more direct measure of the effects of substituting ATMs for banking offices, one needs a more comprehensive analysis.

4. COST EFFECTS OF SUBSTITUTING ATMS FOR BRANCHES

A Cost Function Model

Our approach is to specify separate multi-output cost and profit functions where the quantities of ATMs and banking offices enter directly as substitute deposit delivery methods. In such a model, the variation in total cost or total profit associated with different banks' use of ATMs versus bank offices can be determined

while holding constant the many other influences that affect cost and profit differences among banks. The benefits from joint use of ATMs and branches will be reflected in a scope economy measure. This measure compares the cost or profit of providing deposit services using ATMs and branches jointly versus the cost or profit of using each delivery method separately. Scope economies exist when the cost (profit) of using both delivery methods jointly is lower (higher) than when used separately.[15]

The cost function used expresses total bank operating plus interest costs (C) as being determined by the total deposit, loan, and security output services a bank provides (q_i); the number of banking offices maintained (B); the number of ATMs a bank owns (ATM); and the labor, physical capital, and deposit input prices a bank faces (r_k). More formally, the cost function $C(q_i, B, ATM, r_k)$ is specified using a composite functional form. Developed by Carroll and Ruppert (1984, 1988), the composite form has been shown to provide stable estimates of scope economies, in contrast to other functional forms (Pulley and Braunstein 1992; Pulley and Humphrey 1993). This form has been simplified[16] and can be expressed as:

$$\begin{aligned} C^{(\phi)} = \{[\alpha_0 + \Sigma\alpha_i q_i + \tfrac{1}{2}\Sigma\Sigma\alpha_{ij} q_i q_j + \delta_B B + \tfrac{1}{2}\delta_{B,B} B^2 + \delta_{ATM} ATM + \\ \tfrac{1}{2}\delta_{ATM,\,ATM} ATM^2 + \delta_{B,\,ATM} B \cdot ATM + \Sigma\alpha_{iB} q_i B + \\ \Sigma\alpha_{iATM} q_i ATM] \cdot \exp[\Sigma\beta_k \ln r_k]\}^{(\phi)} + u, \end{aligned} \tag{1}$$

where the superscript (ϕ) refers to the Box-Cox transformation. In sum, there are three banking output services, two deposit delivery methods, and three input prices specified in (1). Further estimation and data details are noted in the appendix.[17]

[15] An alternative way to quantify the trade-off between branches and ATMs would be to determine the (Allen partial) elasticity of input substitution between these two deposit service delivery methods. Unfortunately, accurate data by individual banks on the total cost of supplying only transaction services and the per-transaction price of using an ATM or a branch office needed to compute such a measure from a "transaction cost function" are not generally available. Similarly, detailed transaction volume data for individual banks are also not generally available to derive this measure from a "transaction production function."

[16] The simplifications are that the price-output interaction and price-squared terms that are specified in the full composite model have been deleted in order to reduce collinearity problems and to focus on only those variables and relationships thought to be most important. The coefficient symmetry restriction and the restriction that the three price terms sum to 1.0 for input price linear homogeneity are imposed in estimation.

[17] A translog cost function could be obtained from (1) if $\phi = 0$ and the terms inside the brackets were multiplicative. While the translog form is log linear and thus easier to estimate than is the nonlinear composite form in (1), the translog form does not provide stable and robust estimates of banking scope economies while the composite does. This was shown in Pulley and Humphrey (1993).

Cost Scope Economies Between Branch and ATM Deposit Delivery Methods

Cost savings arise when the predicted total cost of delivering deposit services using offices (B), along with a minimal amount (ϵ) of ATMs, *plus* the predicted cost of using ATMs, along with a minimal amount of offices, *is larger than* the predicted cost of using the median amount of both delivery methods. Expressed formally, this condition is:

$$C[q_i, B(1-\epsilon), \epsilon ATM, r_k] + C[q_i, \epsilon B, ATM(1-\epsilon), r_k] > C(q_i, B, ATM, r_k).$$

This is the only way the costs associated with relying on either offices or ATMs to deliver deposit services can be properly compared while keeping the total use or scale of offices and ATMs constant at their median value.[18] In the inequality, the minimal amount of offices or ATMs (ϵB or ϵATM), added to their use when they are being primarily relied upon to deliver deposit services ($B[1-\epsilon]$ or $ATM[1-\epsilon]$), sum to their median values when used jointly (B and ATM).[19] The minimal amount of either delivery method used (ϵ) is set at 20 percent of their median values since it is not realistic to presume, in today's world, that deposit services will generally be delivered only through banking offices, and certainly not only through ATMs.[20]

The percent amount of cost savings is determined from:

[18] It is not appropriate to compare, say, $C[q_i, B(1-\epsilon), \epsilon ATM, r_k]$ with $C(q_i, B, ATM, r_k)$ since the total use of B and ATM would not be kept constant in the cost comparison. Thus we also need $C[q_i, \epsilon B, ATM(1-\epsilon), r_k]$ so the total use of B and ATM on both sides of the inequality are the same and the cost difference measured will be due to a different *mix* of deposit delivery methods.

[19] The distributions of B, ATM, and the other variables are skewed to the right, so median values are used rather than the means. Importantly, because the cost of producing all banking output is counted twice on the left-hand side of the inequality but only once on the right-hand side, an adjustment is required to the usual scope formula. Specifically, the predicted costs of producing all banking output $C(q_i, r_k)$ has to be subtracted from one of the cost estimates on the left-hand side of the inequality for a proper cost comparison to be made. $C(q_i, r_k)$ is computed using the estimated cost function (1) but with α_0, B, ATM, and their interactions with q_i all set to zero. Although not shown, the same adjustment is applied in (2) by subtracting $C(q_i, r_k)$ in the numerator.

[20] In addition, it has been demonstrated that some cost functions used to predict banking costs at zero or low levels of output provide a more accurate estimate of scope economies when the points of evaluation (here at ϵB and ϵATM) are within the range of the data and reasonably distant from zero. The minimal number of offices (ϵB) for the set of banks in 1992 is $.20(102) = 20$ which is contained within the range of the office data (where the sample minimum number of offices is 2 and the sample maximum is 1,827). Similarly, ϵATM is $.20(103) = 21$ and is contained within its range of 2 to 1,678.

$$\text{SCOPE} = \frac{C[q_i, B(1-\epsilon), \epsilon ATM, r_k] + C[q_i, \epsilon B, ATM(1-\epsilon), r_k] - C(q_i, B, ATM, r_k)}{C(q_i, B, ATM, r_k)} \quad (2)$$

but is perhaps clearer when expressed in words:

$$\frac{\text{cost of using offices} + \text{cost of using ATMs} - \text{cost of using both}}{\text{cost of using both}}.$$

Data from a special *American Banker* survey on ATM ownership for 161 large and small bank holding companies over 1991 and 1992,[21] augmented with Call Report information discussed in the appendix for the same two periods, are used to estimate the banking cost function (1) and compute the apparent cost savings from substituting ATMs for banking offices in (2).

Cost Savings from ATM Use

The estimated cost savings from joint use of ATMs and branch offices to deliver deposit services in 1991 and 1992 is shown in Table 3. Our preferred case—because it is the most realistic—is where the minimal amount of either ATMs or banking offices represents 20 percent of their median value and is in boldface in the table (where $\epsilon = .20$). Evaluated at this point, the estimated cost savings are -2.5 percent in 1991 and -1.4 percent in 1992. The negative value indicates that costs are *higher,* not lower, when ATMs and offices are jointly used to deliver deposit services. Because the ratio of total bank interest and operating expenses to total assets is 7.2 percent, a 2.5 to 1.4 percent increase in total cost due to ATM use would effectively translate into a possible decrease in ROA of 18 to 10 basis points.[22] Put differently, the substitution of ATMs for traditional banking offices represents a "technological change" in deposit service delivery methods that apparently has led to a permanent 2.5 to 1.4 percent upward shift in banks' average cost. However, only the 1991 point estimate of the cost effect of expanded ATM use is significantly different from zero. On balance, the scope measure indicates that ATMs have not lowered costs to banks. On the contrary, costs appear to have been marginally increased rather than reduced.[23]

The relative stability of the cost scope economy estimate is illustrated in Table 3 by changing the point of evaluation, letting ϵ vary between 0.0 and .50. At $\epsilon = 0.0$, which is a standard point for scope economy evaluation, the

[21] The ATM data were published in a special supplement to the *American Banker* for December 7, 1992.

[22] This assumes that (adjusted) revenues per dollar of assets (TR/TA) would be constant so that the basis point change in costs per dollar of assets (TC/TA) also is the change in ROA (since ROA = TR/TA − TC/TA).

[23] No conclusions are changed if, instead of all banks, only the set of low-cost banks on the efficient (thick) frontier were used in the analysis.

Table 3 Cost Scope Economies Between Branch Offices and ATMs: Composite Functional Form

Minimum Percent Use of Alternative Deposit Delivery Method (ϵ)		Scope Economy Estimates 1991 Cost Savings	1992 Cost Savings
(scope)	0.0	−.025 (.021)	−.027 (.036)
	.01	−.025 (.020)	−.026 (.035)
	.05	−.025 (.018)	−.023 (.032)
	.10	−.025 (.016)	−.020 (.028)
	.20	**−.025 (.013)***	**−.014 (.023)**
	.30	−.025 (.012)*	−.011 (.021)
	.40	−.024 (.012)*	−.008 (.019)
(scale)	.50	−.024 (.012)*	−.007 (.019)

* Significantly different from zero at the .05 level.

Notes: Cost scope economies are computed from equations (1) and (2). Profit scope economies are computed in a similar manner. Asymptotic standard errors are in parentheses. All values have been rounded off. None of the cost or profit scope measures are significantly different from zero in 1992, as all t ratios are less than 1.00. See Mester (1987), pp. 436–37, for the method used to compute the standard errors.

estimated cost increase is 2.5 percent in 1991 and 2.7 percent in 1992 but neither value is significantly different from zero.

At the other extreme, when $\epsilon = .50$, the scope calculation actually gives a measure of cost scale economies (see Pulley and Humphrey [1993]). When $\epsilon = .50$, the scope formula (2) compares the predicted costs of two banks each using 50 percent of the median number of offices and ATMs with the predicted costs of one bank using 100 percent of the median number of both delivery methods. Thus the mix of deposit delivery methods is unchanged but their scale of use is being doubled. This is in direct contrast to when $\epsilon = 0.0$ where the scale of use is held constant at the median but the mix of delivery methods is being varied (giving scope economies). The scale economies associated with using more of both branches and ATMs is estimated to raise costs by 2.4 percent in 1991 and 0.7 percent in 1992, but only the 1991 value is significantly different from zero.[24]

In sum, neither the scale nor the scope cost economy measures associated with the delivery of deposit services suggest lower costs. The point estimates are robust to different points of evaluation and, if anything, suggest that costs have risen, not fallen. The statistical significance of the increased cost results,

[24] Note that this is not the same thing as scale diseconomies for the production of deposit and loan services plus their delivery to bank customers. Overall, statistically significant output scale economies exist for smaller institutions but constant average cost—or not important scale economies—seems to be the rule for the largest banks (Berger and Humphrey 1991).

however, is weak as only a few points of scope and scale economy evaluation were significantly different from zero.[25]

5. PROFIT EFFECTS OF SUBSTITUTING ATMS FOR BRANCHES

A Nonstandard Profit Function Model

While costs do not fall as the mix of ATMs and offices used to deliver deposit services is varied, the same may not be true for bank profits. As noted earlier, fees are charged for ATM use. Just as important, the convenience provided by ATMs may enable a bank to retain a more profitable customer base: revenues from non-deposit services may be higher; a bank may be able to pay a lower interest rate on deposits; and a higher monthly minimum balance on deposit accounts may be required. All of these influences could lead to higher bank profits.

The approach to determine the effects of ATMs on bank profits closely follows the approach used to determine cost scope economies above. Profit scope economies are determined from a composite multi-output profit function where bank net income replaces total cost in equations (1) and (2).[26] This reflects a nonstandard profit function. With a standard (textbook) profit function, bank net income would be a function of exogenous output and input prices since the markets for banking outputs and inputs would be assumed to be perfectly competitive. With a nonstandard profit function, banks are assumed to have some market power to vary output prices with their assessment of the value of the product mix offered to consumers, *or* consumers value different mixes of services and bid up prices when these services are offered jointly in a competitive market.[27]

Profit Scope Economies Between Branch and ATM Deposit Delivery Methods

Profit scope economies are computed in an analogous manner to cost scope economies above. Profit scope economies arise when the predicted net income associated with delivering deposit services using offices (B), along with a minimal amount (ϵ) of ATMs, *plus* the predicted net income associated with using

[25] There is some indirect support for this result. Berger, Leusner, and Mingo (1993) found that one large bank provided far too many banking offices: the average office was only about one-half the efficient size, and if these smaller offices were consolidated, total costs could fall by 4 percent.

[26] Specifically, where NI is bank net income, $\ln NI$ replaces $\ln C$ in (1) and $NI(q_i, B, ATM, r_k)$ replaces $C(q_i, B, ATM, r_k)$ in (2).

[27] Some studies supporting price-setting behavior in markets for banking output are Hancock (1986), Hannan and Liang (1990), and English and Hayes (1991).

ATMs, along with a minimal amount of offices, *is smaller than* the predicted net income associated with using the median amount of both delivery methods. Thus profit scope economies exist—and profits are higher—if the scope measure is positive (just as cost savings would exist if the cost scope measure were positive).

Increased Profits from ATM Use

The estimated increase in net income from joint use of ATMs and branch offices to deliver deposit services is shown in Table 4. Our preferred case is still where the minimal amount of either ATMs or banking offices represents 20 percent of their median value and is in boldface in the table (where $\epsilon = .20$). Evaluated at this point, the estimated increase in bank net income is 3.6 percent in 1991 and 1.6 percent in 1992. Since ROA in 1992 was 92 basis points, the increased use of ATMs appears to have permanently contributed about 3.3 to 1.5 basis points to banks' ROAs. However, only the 1991 profit scope economy measure is significantly different from zero. At the usual point of scope economy evaluation of $\epsilon = 0.0$, neither profit scope measure is significant. Therefore, although the point estimates show a rise in bank net income, ATMs seem to have only marginally raised net income or profits to banks. The same conclusion applies to the profit scale measure (at $\epsilon = .50$) as this value is only significant in one year.

Table 4 Profit Scope Economies Between Branch Offices and ATMs: Composite Functional Form

Minimum Percent Use of Alternative Deposit Delivery Method (ϵ)		Scope Economy Estimates	
		1991 Profit Increase	1992 Profit Increase
(scope)	0.0	.049 (.030)	.031 (.037)
	.01	.048 (.029)	.031 (.036)
	.05	.045 (.026)	.027 (.033)
	.10	.042 (.022)	.023 (.030)
	.20	**.036 (.017)***	**.016 (.024)**
	.30	.032 (.015)*	.011 (.022)
	.40	.029 (.014)*	.009 (.020)
(scale)	.50	.029 (.014)*	.008 (.020)

* Significantly different from zero at the .05 level.

Notes: See Table 3.

6. SUMMARY AND CONCLUSIONS

The greatest change in the availability of deposit services over the last two decades has been the introduction of ATMs to augment, and replace, the traditional bank branch office in delivering these services. In 1973, there were 40,600 banking offices and less than 2,000 ATMs. On average, one banking office or ATM served 3,700 individuals (age 18 and older). ATMs were not intensively used as there were only five ATMs for each 100 banking offices. By 1992, there were 63,900 offices and 90,000 ATMs. Now there are three banking offices or ATMs for each set of 3,700 individuals—an expansion of convenience per person of over 200 percent. As a total, there are now 141 ATMs for each 100 banking offices. The increased availability of ATMs has benefited bank customers by both expanding the number of locations where deposit services can be obtained and by the fact that ATMs are typically "open" 24 hours a day.

Unfortunately, the expectation that ATMs would reduce bank costs has not been realized. Indeed, costs appear to be slightly higher, although the effect is weak. It is true that substantial scale economies exist for ATMs and that current transaction volumes are high enough to realize these economies. However, the potential benefits which should follow from the fact that an ATM transaction costs about half as much as a similar transaction in a traditional banking office has been largely offset by depositors who, because of the increased convenience of ATMs, use them up to twice as often as they previously used a banking office. Thus while ATMs were successful in reducing the cost of each depositor transaction, depositors increased the number of transactions, leaving total costs relatively unchanged or slightly higher. This suggests that the cost savings which could have been reaped by banks by substituting ATMs for branch offices has instead largely flowed to depositors who have shown their preference for the increased convenience provided by ATMs by substantially expanding the number of transactions they undertake.

The negative effect from higher costs can be offset if the revenues raised from bank provision of ATMs have been sufficient to raise bank profits. While profits are higher with ATM use, the effect is weak and is not consistently significant. Even so, profits appear to be marginally higher with ATM use, which likely represents a small net benefit to banks. Overall, however, it is probably the case that users of bank deposit services have benefited more from the change in the delivery of these services than have the banks.

APPENDIX

The ATM data are for 161 bank holding companies for 1991 and 1992 from the *American Banker* (special supplement, December 7, 1992) plus Call Report data on these same institutions for the same time periods. The medians of the data used are shown in Table A1 for 1992, while the parameter estimates for 1992 are in Table A2.

Table A1 Median Values of the Data: All Banks in 1992

Total cost (C)	\$.372 b	Number of offices (B)	102
Net income (NI)	\$.042 b	Number of ATMs (ATM)	103
Value of all deposits (q_D)	\$4.163 b	Price of labor (r_L)	\$33,200/yr.
Value of loans (q_L)	\$2.647 b	Price of capital (r_K)	.326
Value of securities (q_S)	\$1.512 b	(depreciation/book value)	
(b = billion)		Price of deposits (r_D)	4.50%

Note: Sample size was 161 for the cost function but 152 for the nonstandard profit function: nine observations with negative net income were deleted from the 1992 estimation.

Table A2 Parameter Estimates: Composite Cost and Profit Functions for 1992

Coefficient	Variable	Cost	Profit
ϕ	Box-Cox Parameter	.341*	.347*
α_0	Constant	−7.0E + 04	−6.9E + 04
α_D	Total Deposits	.305*	.321*
α_L	Loans	.438*	.426*
α_S	Securities	.407*	.415*
α_{DD}	(Deposits)^2	−.31E − 08	−.12E − 08
α_{LL}	(Loans)^2	−.35E − 07	−.25E − 07
α_{SS}	(Securities)^2	.26E − 07	.27E − 07
α_{DL}	Deposits · Loans	.18E − 07	.15E − 07
α_{DS}	Deposits · Securities	.16E − 07	.15E − 07
α_{LS}	Loans · Securities	−.59E − 07	−.59E − 07
δ_B	Offices	−1.1E + 03	−9.5E + 02
δ_{ATM}	ATMs	1.3E + 03	1.3E + 03
$\delta_{B,B}$	(Offices)^2	−2.39	−4.98
$\delta_{ATM,ATM}$	(ATMs)^2	−4.61	−4.56
$\delta_{B,ATM}$	Offices · ATM	7.74	9.21
$\delta_{D,B}$	Deposits · Offices	−.38E − 03	−.36E − 03
$\delta_{L,B}$	Loans · Offices	.57E − 03	.54E − 03
$\delta_{S,B}$	Securities · Offices	−.33E − 03	−.29E − 03
$\delta_{D,ATM}$	Deposits · ATMs	−.19E − 03	−.19E − 03
$\delta_{L,ATM}$	Loans · ATMs	.97E − 04	.45E − 04
$\delta_{S,ATM}$	Securities · ATMs	.80E − 03	.82E − 03
β_L	ln(r_L)	.127*	.119*
β_D	ln(r_D)	.783*	.779*
Log of the likelihood function		99.54	94.26

* Statistically significant at the .05 level.

Note: Although it is difficult to identify precisely the individual first- and second-order coefficients and interaction terms in a second-order (quadratic or log-quadratic) output specification, functions of those coefficients—such as the scope measure—can be identified with greater precision since correlations among coefficients are accounted for in the formulas for (approximate) asymptotic standard errors.

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