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Most of the research that uses income to measure economic well-being shows that while unemployment has a strong positive effect on poverty rates, inflation has very little effect. This paper considers the impact of inflation and unemployment on poverty, using a poverty rate based on goods and services actually consumed, rather than on income. The findings suggest that increases in unemployment are associated with increases in both the consumption poverty rate and the conventional income poverty rate. However, inflation seems to have a robust and relatively large positive influence on consumption poverty, indicating that inflation may harm the poor more than was previously thought.

Since 1979, the cost to the Federal Reserve of processing an automated clearinghouse (ACH) transaction has fallen dramatically. The authors of this study find that three factors — scale economies, technological change, and lower input prices — each contributed significantly to this price decline. Their results also show that substantial scale economies could still be achieved in ACH payments processing. This research should be of broad interest to economists because the data provide a rare, detailed glimpse into the workings of a service industry.

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Inflation, Unemployment, and Poverty Revisited

by Elizabeth T. Powers

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Introduction

A small but influential body of literature has attempted to estimate the effect of selected macroeconomic variables on poverty.[1] Such exercises may serve several purposes. For example, general knowledge of predictable empirical relationships among these variables might aid fiscal planning. However, most of this work has been motivated by "the frequent outcries against inflation on the grounds of its adverse effects on the distribution of income."[2] This literature consistently finds that inflation has a relatively minor impact on the incidence of poverty and on the well-being of poor and near-poor households. Because most economists working in this area assume that there is a direct trade-off between inflation and unemployment, controllable by the policymaker, the critical comparison is between the effects of the inflation and unemployment rates on poverty.

This paper considers the relationship between these macroeconomic variables and an alternative poverty measure that is based on consumption rather than income. Otherwise, I follow the methodology of the existing literature closely. My research findings suggest that changes in the unemployment rate are important in explaining variation in both the conventional income poverty rate and a consumption-based poverty rate (which I call the JS poverty rate, after work by Jorgenson and Slesnick [1987, 1990] and Slesnick [1993]). However, in sharp contrast to previous findings that inflation has very little effect on income poverty, I find a robust and relatively large positive relationship between inflation and the consumption poverty rate. Thus, my findings suggest that inflation may have a more adverse effect on poverty than was previously thought.

Before explaining the methodology and findings, it is important to note that there are several possible avenues for improving on the existing literature. Perhaps most seriously, the relationship between inflation and unemployment, long a subject of intense debate, is not modeled. Typically, aggregate indicators of poverty such as the share of all income received by the 20

■ 1 For example, while it is not the focus here, aggregate economic growth is a frequently used macroeconomic indicator variable in this literature. See Powers (1995) for a discussion.

■ 2 See Blinder and Esaki (1978), p. 604.

percent (quintile) of households reporting the lowest income, or the poverty rate (the percent of the population living in households with income below a given level), are simply regressed on measures of unemployment and inflation. Inflation and unemployment rates are treated as if they have no influence on each other, or are not both partly determined by some common factor. This is at odds with most theoretical treatments of the macroeconomy, and ignoring the existence of these relationships can result in unreliable estimates.

Use of the quintile share of income as a poverty indicator can also be misleading. In many cases, this variable is not informative about changes in the welfare of the poor. For example, suppose that households in the top income quintile are taxed and the proceeds destroyed. By definition, the total income share of the bottom group must rise, yet it is obvious that this latter group is not better off in any substantive way. For similar reasons, empirical estimates of the influences of inflation and unemployment on quintile shares are not easily interpreted. Inflation or unemployment may harm low-income groups absolutely, even while their effects on quintile shares are positive or negative.[3]

Finally, except for the work of Cutler and Katz (1991), this literature has developed under the assumption that income poverty concepts adequately measure economic well-being. In the past, this has been a matter of necessity, because income data were the most comprehensively and consistently collected. However, economic theory suggests that the goods and services actually consumed by a family or individual are a better measure of their well-being (the economist's ideal measure being utility). Poverty measures based on income and consumption are expected to differ because, in principle, money income and consumption can differ substantially.[4] This means that *who* is classified as poor can vary across the two measures. Further, the predominant economic model of consumption argues that households attempt to protect their standard of living from short-term income swings. This implies more year-to-year variation in household income than in consumption. Hence, the income poverty count should also include more families who are transitorily poor, while consumption poverty should include more families who view their status as persistent. For all these reasons, relationships found to hold with respect to poverty measured on an income basis may not be robust with respect to poverty measured on a consumption basis.

Because of the difficulties in interpreting the quintile-share measures of well-being, I focus exclusively on the poverty rate.[5] However, the poverty rate has some severe limitations of its own. After all, it is merely a head count of those below a particular threshold, and changes in macroeconomic conditions can dramatically affect the well-being of the poor without changing the actual head count at all. Therefore, it is important to remember that the poverty rate portrays only a single (albeit important) feature of the nation's poverty situation.

While the modeling of the macroeconomy in previous work is obviously open to question, there is so little agreement on the proper model that such an approach is unappealing. Instead, I accept the premises on which the previous literature rests, and ask whether these findings are robust with respect to the poverty concept employed. Thus, this paper is best interpreted as a sensitivity analysis of the previous findings vis-à-vis inflation, unemployment, and the poverty rate.

The paper's first section discusses and interprets the findings of the previous literature. Section II traces the history of the official measure of income poverty and considers its flaws. The development of the alternative historical series of consumption poverty rates presented in Slesnick (1993), and the differences between it and the conventional poverty series, are discussed in section III. Section IV revisits the issue of inflation, unemployment, and poverty using alternative poverty and inflation measures. Section V concludes.

I. Unemployment, Inflation, and the Conventional Poverty Rate

In this section, I discuss and update the previous literature's findings on inflation, unemployment, and income poverty. To interpret the

3 In fact, it is easy to construct a model in which the impact of inflation is consistently positive or negative on all incomes, but the relationship between inflation and any quintile's share, and even the ratio of low to high shares, is nonmonotonic.

4 In theory, low-income households could also be drawing on savings, borrowing against future income, receiving gifts or government transfers of goods and services, or even getting income from the underground economy. Of course, whether they actually do so is an empirical question.

5 While the poverty rate has its own limitations, at least its predicted relationship with the variables of interest here is unambiguous.

findings, however, it is important to consider the microfoundations of income poverty and to understand how changes in macroeconomic variables are transmitted into changes in poverty rates. How might higher overall unemployment affect the number of persons living in poverty? The majority of families rely on labor-market earnings for most of their income, so episodes of unemployment may result in large income declines. It is also well known that unemployment in cyclical downturns is disproportionately borne by people whose earnings are low to begin with—those whose incomes are most vulnerable to slipping below the poverty level.[6] These factors are expected to produce a strongly positive relationship between unemployment and poverty rates. However, there are other, potentially mitigating, factors. Some have theorized that the pattern of wages over the business cycle could be procyclical,[7] and that dependency on government transfer payments might also lessen the poverty rate's sensitivity to unemployment by reducing the role of earned income.

Dependence on unindexed income is the obvious channel through which inflation might affect income poverty rates. Households that rely on nominally fixed payments for a substantial portion of their income could be driven into poverty by inflation; this implies a positive relationship between inflation and poverty rates. The primary sources of nominally fixed income are means-tested transfer payments (Aid to Families with Dependent Children [AFDC] and states' General Assistance programs being the only significant unindexed cash-transfer programs) and the minimum wage.[8] It is also possible that employers exercise temporary market power in inflationary periods, allowing real wages to fall in the short run. Finally, as the next section discusses, the poverty line was probably overindexed for inflation throughout the 1970s and 1980s, implying that some portion of poverty-rate increases may be explained by increased inflation itself.

The primary studies on inflation, unemployment, and the size distribution of income in the United States are those of Blinder and Esaki (1978), Blank and Blinder (1986), Blank (1993), Cutler and Katz (1991), and Mocan (1995). Except for Blinder and Esaki (who estimate only income shares), all of these studies estimate straightforward empirical relationships between poverty rates and macroeconomic variables.[9]

Blank and Blinder (1986) first examined the relationship between unemployment, inflation, and official income poverty rates for families and persons. Their regression findings indicate that inflation and unemployment rates were both positively related to the percent of all persons living in poverty during the 1959–1983 period. However, while inflation was associated with an increase in the steady-state poverty rate, this effect was only one-seventh the magnitude of the poverty-increasing effect of a rise in the unemployment rate. This led Blank and Blinder to conclude that while both unemployment and inflation worsen poverty, the empirical evidence supports their belief that "unemployment, not inflation, is the cruelest tax." Blank (1993) also found a significantly positive relationship between inflation and poverty rates. In contrast, Cutler and Katz (1991) and Mocan (1995) reported a relatively small *negative* relationship between inflation and poverty. A strong, robust, positive relationship between poverty and unemployment has been consistently observed.

Because of revisions to data series as well as the availability of new data since the original studies appeared, I have updated some representative findings in the literature using the poverty rate for persons, as computed by the Census Bureau from 1959 to 1992 (table 1). The specification in the first column includes an intercept term, an inflation measure (the growth rate of the Consumer Price Index for all urban consumers, or CPI-U), the unemployment rate for prime-age males, and additional explanatory variables, including the ratio of the poverty level for a family of four to mean household income, and a trend for the years after 1983. In the second column, the one-period lag of the poverty rate is added to the specification as a crude control for any dynamic features of the evolution of poverty.[10] The unemployment rate for males

■ 6 While it is probably safe to assume that families starting out nearest the poverty line are most vulnerable to crossing it, there is also substantial income mobility from year to year in the U.S. economy. It is possible that some people whose incomes put them well above the poverty line one year might find themselves below it the next.

■ 7 The evidence on this matter is inconclusive.

■ 8 It is doubtful that these income sources exert an important influence on the poverty rate. Very few families of any kind contain a minimum wage earner (see, for example, Horrigan and Mincy [1993]). And, while real AFDC benefits have been declining over the past 20 years, the effect on per capita benefits has largely been mitigated by declining household sizes.

■ 9 A number of studies apply this methodology to foreign economies, a recent example being Yoshino (1993) on Japan. Minarik (1979) used an alternative microsimulation approach to examine the effect of inflation alone on the size distribution of income.

■ 10 The specifications reported in the first two columns are similar to those presented in Cutler and Katz (1991).

TABLE 1

Regression Findings for Income Poverty, 1959–1992

Dependent Variable: Income Poverty Rate for Persons			
Explanatory Variables			
Constant	−10.44[a] (1.29)[b]	−6.65[a] (1.09)	−5.10 (4.185)
Poverty line/ mean income	0.635[a] (0.029)	0.289[a] (0.058)	0.366[a] (0.111)
Inflation (growth in CPI-U)	−0.114[a] (0.043)	0.065[c] (0.039)	0.081[c] (0.049)
Prime-age-male unemployment rate	0.433[a] (0.068)	0.323[a] (0.046)	0.584[a] (0.224)
Post–1983 trend	0.338[a] (0.054)	0.199[a] (0.042)	
Lagged-income poverty rate		0.586[a] (0.090)	0.371[a] (0.119)
Post–1982 dummy (1983–1992 = 1)			−3.41 (2.39)
Government transfers to persons/GNP			−0.278 (0.237)
Interactions with Post-1982 Dummy			
Prime-age-male unemployment rate			−0.748[a] (0.190)
Government transfers to persons/GNP			0.787[a] (0.247)
Inflation (growth in CPI-U)			−0.039 (0.149)
Adjusted R^2	96.8%	98.5%	98.6%
Number of observations	34	33	33

a. Significantly different from zero at the 5 percent level or greater.
b. Standard errors are in parentheses.
c. Significantly different from zero at the 10 percent level or greater.
SOURCE: Author's calculations.

aged 25–54 is used to capture unemployment effects on poverty, since the total unemployment rate is influenced by demographic trends that may independently affect the income poverty rate. The ratio of the poverty line to mean household income is intended to control for the shape of the income distribution near the poverty line (see Danziger and Gottschalk [1986]). Finally, the post–1983 trend attempts to account for that era's unusually and persistently high poverty rate (Cutler and Katz [1991], Blank [1993]).

In the first two columns, the unemployment rate shows a strong positive effect on the income poverty rate.[11] An increase of one percentage point in the prime-age-male unemployment rate raises the poverty rate by an estimated 0.3 to 0.4 percentage point. According to the first column, periods of high inflation are associated with poverty-rate reductions. An increase of one percentage point in the inflation rate leads to a reduction of 0.1 percentage point in the poverty rate. However, the findings with respect to inflation are sensitive to specification; the findings reported in the second column suggest that inflation has a (weakly) positive effect on the income poverty rate.

The final specification, reported in the last column, is similar to those in Blank (1993) and Blank and Blinder (1986). In addition to the previous variables, Blank includes a measure of government policy (government transfers to persons divided by GNP) and tests for structural change in the relationship between unemployment, policy, and poverty after 1982. I have added a term to test for a structural change in the inflation effect as well. Unemployment has the strongest effect in this specification, while inflation has only a weakly positive impact. All of the macroeconomic variables appear to have perverse effects in the post–1982 world, as noted by Blank.

Recently, Mocan (1995) has presented a more elaborate econometric treatment of the relationships between unemployment, inflation, and poverty. He specifies poverty rates as a function of unemployment, inflation, and real wages, and uses a "flexible" model of the trend in the poverty rate. The problem is that the deterministic trends previously used in this literature may be inappropriate if the trend in the poverty rate is subject to stochastic disturbances. This issue is important because proper detrending of the data is critical for reliable parameter estimates. Mocan also decomposes unemployment into its short- and long-run components and inflation into its anticipated and unanticipated components, and analyzes black and white poverty rates separately.[12] While Mocan finds that cyclical unemployment has almost no effect on income poverty, long-run (structural) unemployment has a significantly positive effect. He also finds that both expected and unexpected inflation significantly *reduce* poverty,

11 It should be noted that to preserve comparability with previous studies, I do not correct for the obvious autocorrelation in all of the specifications in table 1. However, corrected estimates (which are not reported) are qualitatively similar.

12 Blank and Blinder (1986) also decomposed inflation, but found no significant differences between unanticipated and anticipated inflation effects.

with the former having the larger impact. The negative effect of inflation on the person poverty rates for blacks and whites is about one-third of Mocan's estimated poverty reductions from a decrease in structural unemployment.

To summarize the literature's findings, unemployment is consistently estimated to have a strong positive effect on the income poverty rate, suggesting that joblessness is responsible for pushing many households' incomes below the poverty level. This finding is quite robust with respect to various empirical specifications. While the estimated effect of inflation is very sensitive with respect to specification, it seems to have at most a small positive impact on the poverty rate, and may even be associated with poverty-rate *declines*.

Unfortunately, these findings are developed in the context of a poorly specified measure of poverty. A consumption-oriented approach to poverty suggests that the important factors are the total resources available to a family over long periods, and the family's ability to rearrange these resources over time. If consumption and income poverty rates turn out to be very different, one expects that the findings vis-à-vis inflation, unemployment, and poverty will also be very different—for two reasons. First, as I discuss below, the mechanisms by which unemployment and inflation may be translated into consumption poverty are quite different from those influencing income poverty. This suggests that the relationship of macroeconomic variables to consumption poverty is potentially very different from their relationship to income poverty. Second, the income poor and the consumption poor may be dissimilar groups of people. (For example, they appear to vary in age and racial composition, according to Slesnick [1993].) Since the response to macroeconomic conditions is undoubtedly heterogeneous across the population, changing the type of households under consideration should also change the aggregate relationships.

Of course, if income poverty is a close approximation of the underlying "true" consumption poverty rate, these issues will be significant only in theory, not in practice. In the next section, I review Slesnick's (1993) calculation of consumption poverty.[13]

II. The Mismeasurement of Poverty

A Brief History of the Poverty Line

The official government poverty rate is the proportion of the population whose pretax income falls below specified levels, called "poverty thresholds" or "poverty lines." Today's official poverty thresholds have their antecedents in the poverty lines developed for the Social Security Administration by Orshansky (1988) in the early 1960s. Because budget studies from the 1950s found that the typical low-income family spent about one-third of its budget on food, Orshansky took the USDA's Economy Food Plan (a nutritionally adequate but inexpensive collection of food items) and multiplied it by three to arrive at a level of total expenditures designated as the poverty line.

Poverty thresholds were further refined for the heterogeneous nutritional requirements of families with different structures. Until 1981, a particular family's threshold depended on family size, sex and age of the household's head, number of related children under 18, and farm or nonfarm residence. Smaller families devote a relatively smaller share of total expenditures to food; women have lower caloric requirements than men; children eat less than adults; and farm families can consume home-grown food. All of these considerations suggested lower multiplicative factors, and hence lower poverty expenditure thresholds, all else being equal.[14] In 1981, calculations of differences due to sex of the household head and farm versus nonfarm residence were eliminated by legal challenges.

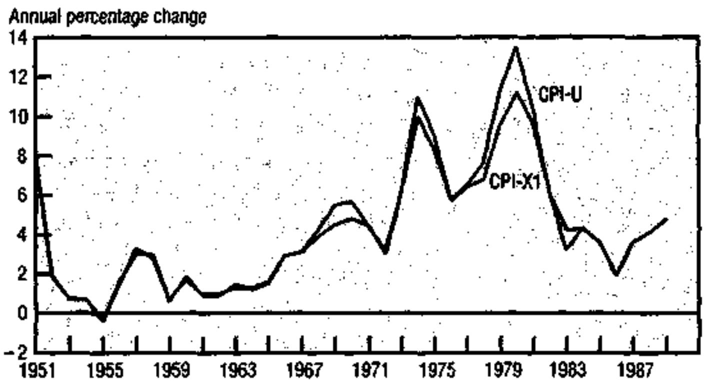
Nominal thresholds must be adjusted over time to reflect declines in purchasing power. Prior to 1981, the nominal poverty line was increased by food-price inflation only. By ignoring other prices, these adjustments sometimes overstated, sometimes understated, the increase in total nominal expenditures required to maintain a constant standard of living. Since 1981, the CPI-U has been used to inflate the official poverty thresholds from their 1963 values to current dollars.

13 The material in section II is drawn primarily from Slesnick (1993) and Ruggles (1990).

14 Indeed, it is possible to differentiate along many more characteristics, as suggested by Slesnick (1993).

FIGURE 1

Alternative Inflation Rates, 1951–1989



SOURCE: Author's calculations.

Problems with the Official Poverty Rate

As Slesnick (1993) points out, the conceptual basis for the official poverty statistic, based on an expenditure concept, is fundamentally sound. However, several features of the poverty thresholds are simplistic and may bias the measurement of poverty. Foremost among these are benchmarking against food consumption and the inflation adjustment. Using family equivalence scales based entirely on food needs will in some cases understate, and in other cases overstate, efficiencies in the shared consumption of nonfood commodities. For example, a childless couple may need almost twice as much food as one person, but they will not need twice as many rooms in their apartment. Thus, multiplying their Economy Food Plan figure by three may lead to a gross overstatement of their minimal expenditure requirements. Because the food equivalence scale will understate efficiencies of shared consumption in other items, the direction of the total bias that results from relying solely on food shares is unpredictable a priori.

Several obvious issues are raised by adjusting the poverty thresholds by a single inflation rate each year, and several problems are peculiar to the CPI-U. First, an increase in the general price represents the combined effect of increases (and/or decreases) over all prices, but all prices do not necessarily rise at the same rate. When, for example, inflation is concentrated in the price of necessities, the poor, who devote a greater fraction of total expenditures to these items, will be harmed more than others. This suggests that poverty thresholds should be adjusted by price indexes that are relatively more sensitive to rising prices of items consumed intensively by the poor, rather than by the CPI-U, which reflects inflation based on expenditure patterns of the average family.

Another potential problem of applying a single inflation measure to poverty thresholds is that expenditure patterns may adjust in ways that mitigate welfare losses from price changes. In theory, families can accommodate fairly significant inflationary episodes by adjusting the types and relative quantities of goods they consume.[15] For instance, when beef prices rise relative to chicken prices, consumers may substitute chicken for beef. These behavioral responses result in smaller declines in living standards than if expenditures remained frozen in their former patterns. Since the CPI-U is only infrequently reweighted for changes in expenditure patterns (and not of the poor, but of the average family), applying it to the poverty line overstates the increase in poverty thresholds required to approximate the same level of well-being.

A final problem, peculiar to the CPI-U itself, is its treatment of housing. Before 1984, the housing component was set equal to the *financial cost* of housing, not the flow of housing services. Thus, periods of high mortgage rates are periods of overstated inflation in the CPI-U series. Figure 1 shows both the CPI-U and the alternative CPI-X1, which uses rental costs as a proxy for housing service prices. The CPI-U overstates inflation in the late 1960s and late 1970s, implying that poverty thresholds rose by more than the amount needed to maintain a constant standard of living, and overstating recent poverty rates. After 1984, the two price indexes are the same.

With the exception of the housing error, the above factors make a relatively minor contribution to the mismeasurement of poverty (Slesnick [1993]). The most serious divergence between theory and implementation is the use of pretax income, rather than expenditures, as the yardstick for poverty. This practice accounts for most of the mismeasurement of poverty. In the next section, I explore the construction of alternative consumption-based poverty rates and the biases introduced by the use of income- rather than consumption-based rates.

15 That is, substitution as well as income effects are associated with price changes.

III. A Consumption-Based Poverty Rate

The accurate estimation of consumption-based poverty rates is a daunting task. Slesnick (1993) overcomes several obstacles to arrive at a series that addresses the many problems discussed in the previous section. His estimates are developed under the assumption that families act as life-cycle consumer units, saving and dissaving to smooth consumption over time.[16] An implicit assumption is that the fraction of "misers" in the population is small. Presumably, for most families, a consumption poverty classification reflects low resources rather than a preference for low consumption.

Slesnick's basic consumer data are from the Consumer Expenditure Surveys (CES) for 1960–1961, 1972, 1973, and 1980–1989.[17] Measuring poverty on the basis of consumption, rather than income, is not a simple matter of comparing CES expenditure data to the standard poverty thresholds. First of all, expenditure and consumption are not equivalent concepts. For example, contributions to retirement funds (including Social Security taxes), which the CES records as expenditures, are really savings, since they contribute directly to future living standards. Contributions or gifts to other households, while available, are not used by Slesnick, since a consistent treatment would greatly complicate the modeling of consumption. As in computing official poverty status, Slesnick excludes in-kind transfers of housing subsidies and health care from his measure of consumption, although conceptually they should be included. Finally, many goods are consumed over long periods and not immediately upon purchase. Expenditures for these "durable" goods may occur all at once or over a period of years (homes and cars are frequently paid for in this way). There is no reason to expect payment schemes to exactly match the flow of value from the consumption of these services. Instead, Slesnick imputes the rental equivalent (what one would be willing to pay to rent the identical item) for durables in each survey year.

The JS equivalence scales used to adjust for differences across family types are more detailed than the official equivalence scales. They measure how expenditure patterns for all items (not just food) change when household composition changes. In contrast to the official rates, which are based solely on nutritional requirements, and which vary only according to size and age characteristics of families and individuals, the "JS equivalence scales ... vary over any set of demographic attributes that influence household expenditure patterns" (Slesnick [1993]).

Slesnick addresses many of the indexing problems associated with the conventional poverty rate. For any combination of price changes, he estimates the minimum nominal change in total expenditures necessary to maintain a constant standard of living, which amounts to a specific cost-of-living index for each household. The index is applied to the base-year poverty threshold (which has been converted to a consumption-equivalent basis). This general deflator accounts for several factors excluded by the CPI-U, including the fact that price changes affect families with different consumption patterns differently and lead to substitution of less expensive for more expensive commodities. However, Slesnick shows that these adjustments' effects on measured poverty are quite small. The primary impact on poverty rates comes through the correction for the overstatement of inflation in the CPI-U due to the mistreatment of owner-occupied housing costs.

Figure 2 shows the official income poverty rate and the JS consumption poverty rate for 1959–1989. Both the levels and trends of the two rates are quite different. Except for a period in the late 1960s, the official poverty rate is higher than the JS rate. Both rates decline from 1961 to the beginning of the 1970s. However, they paint dramatically different pictures of recent poverty trends. Because the JS family equivalence scales set a relatively lower poverty threshold for female heads than do the official equivalence scales, JS poverty continues to trend downward over the 1970s, when the proportion of female heads in the general population was rising dramatically and pushing up the conventional poverty rate.[18] While the official rate indicates a strong resurgence in poverty throughout the early 1980s and persistently high rates thereafter, the JS rate, after a sharp increase around the time of a recessionary trough in

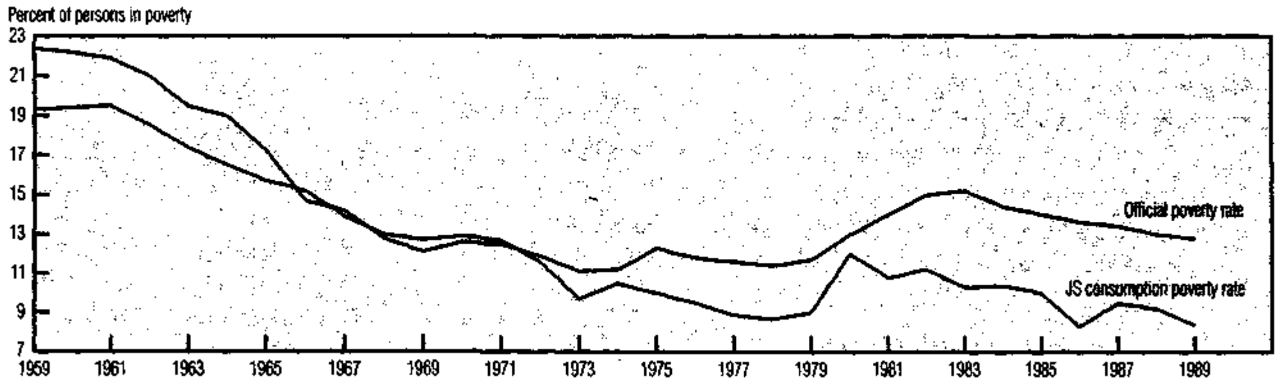
■ **16** Since a brief discussion can convey only the major contributions, readers with a deeper interest in the methodology and implementation should consult Slesnick (1993) and the references therein. It should also be noted that the application of the life-cycle model to low-resource households is controversial.

■ **17** Imputation methods involving auxiliary information from the Current Population Surveys are used to derive poverty rates for the years not covered by the CES. Given the available data, this is the best one can do. The imputation process probably errs on the side of making the consumption poverty measure and the official poverty measure more similar.

■ **18** The primary reason for the lower JS thresholds for female-headed households is that children in these families are on average younger than children in two-parent families and so consume less.

FIGURE 2

Alternative Poverty Rates, 1959–1989



SOURCES: Author's calculations; and Slesnick (1993).

1980, shows continued progress in the war on poverty throughout the 1980s.

Although he does not compute the degree of overlap between the income-poor and consumption-poor groups, evidence provided by Slesnick from the CES supports the notion that the officially poor group is dominated by those with only temporarily low incomes and fairly high consumption. For example, in a typical year, 40 percent of the income poor are homeowners (as are 60 percent of the general population); in contrast, only 17 percent of the consumption poor own their homes. Thus, a significant minority of the income poor receive substantial service flows from housing, while most of the consumption poor do not. The consumption poor also devote a larger share of total expenditures to necessities such as food (ranging from 31.6 percent to 37.3 percent over the 1961–1989 period) than do the income poor (22.2 percent to 28.1 percent). The life-cycle model implies that dissavers view their low income as a transitory circumstance; indeed, Slesnick finds substantial dissaving occurring among the income poor. While 59 percent to 76 percent of the income poor dissave over the CES surveys, only 21.7 percent to 36.4 percent of the consumption poor dissave, suggesting that the consumption poor view their lack of resources as a permanent condition.

The divergence between the two poverty measures is expected to grow over time, since the poverty line is an absolute—not a relative—notion of well-being. When average income is fairly low, there are relatively more people whose "typical" annual income is near or below the poverty line. As average real income grows, as it has since 1960, there are relatively fewer people whose typical income is below the poverty line. Thus, the income-poor population is increasingly dominated by people with extraordinarily bad income realizations—just the people for whom consumption does not equal income.

IV. Inflation, Unemployment, and Poverty Revisited

Before discussing the empirical approach and findings, it is useful to describe the ways in which inflation and unemployment might be expected to influence consumption poverty. Unemployment may affect consumption poverty rates in several ways. If the household is liquidity constrained (so that consumption is limited to current income), then a spell of unemployment may result in both income and consumption poverty. When the household is not liquidity constrained, a spell of unemployment should be harmful to the extent that it decreases permanent, but not transitory, income. For example, if earnings losses in recessions are offset by increased opportunities in expansions, cyclical unemployment should not affect permanent income or consumption poverty rates. However, if the labor market rewards continuity in employment, time out of the labor force may permanently reduce income, and hence consumption. Finally, periods of high unemployment may be periods of heightened uncertainty about the future, which may lead to reduced consumption and a higher incidence of consumption poverty.

TABLE 2

Estimated Effects of Unemployment and Inflation on Income Poverty, 1959–1992

Dependent Variable: Income Poverty Rate—Persons[a]				
Explanatory Variables				
Constant	−0.26 (0.192)[c]	−0.179 (0.146)	−1.62[b] (0.279)	−1.61[b] (0.275)
Inflation (CPI-U)	−0.015 (0.054)	−0.052 (0.054)	−0.036 (0.061)	
Inflation (CPI-X1)				−0.041 (0.056)
Prime-age-male unemployment rate	0.417[b] (0.099)	0.373[b] (0.104)	0.396[b] (0.095)	0.390[b] (0.095)
Demographic controls[d]			yes	yes
Real hourly earnings		−0.811[b] (0.327)		
Autocorrelation coefficient	0.50[b] (0.151)	0.335[b] (0.169)	n.a.	n.a.
Adjusted R^2	43.5%	57.7%	67.6%	67.9%
Number of observations	33	32	30	30

Dependent Variable: Consumption Poverty Rate—Persons[a]				
Explanatory Variables				
Constant	−0.389[b] (0.147)	−0.262[e] (0.155)	−1.349[b] (0.414)	−1.375[b] (0.433)
Inflation (CPI-U)	0.207[b] (0.076)	0.180 (0.073)	0.204[b] (0.068)	
Inflation (CPI-X1)				0.219[b] (0.088)
Prime-age-male unemployment rate	0.453[b] (0.153)	0.317[b] (0.158)	0.347[b] (0.144)	0.322[b] (0.150)
Demographic controls[d]			yes	yes
Real hourly earnings		−0.106[b] (0.485)		
Adjusted R^2	26.9%	35.7%	41.9%	36.4%
Number of observations	30	29	30	30

a. All data are first-differenced.
b. Significantly different from zero at the 5 percent level or greater.
c. Standard errors are in parentheses.
d. Demographic controls include percent of persons over age 65, percent of white persons in population, and percent of families headed by a woman.
e. Significantly different from zero at the 10 percent level or greater.
SOURCE: Author's calculations.

Inflation may also be associated with heightened uncertainty and increased consumption poverty. Inflation can reduce permanent income (and hence consumption) by increasing the discount rate applied to future income flows; this would also tend to increase the consumption poverty rate. There are at least two other ways in which higher inflation might be associated with higher consumption poverty rates. First, inflation tends to benefit debtors at the expense of creditors, thus eroding asset values. Both liquidity constraints and imperfect access to useful financial instruments may cause the net wealth of the consumption poor to be weakly hedged against inflation. Second, it is possible that households are slow to adjust their consumption patterns to rapidly rising prices. This, too, might contribute to a higher rate of consumption poverty.

Rather than simply recomputing the regressions reported in table 1 using the JS poverty rate in place of the conventional income poverty rate, all the data are first-differenced beforehand.[19] This simple but effective method of detrending the variables is a special case of the flexible trend model employed in Mocan (1995). The top panel of table 2 presents the findings for the conventional poverty rate, and the bottom panel for the JS poverty rate.[20]

In the first column are the findings for the regression of the poverty rate on an intercept, the prime-age-male unemployment rate, and the growth of the CPI-U (with all variables first-differenced). For the conventional poverty rate, the findings remain qualitatively similar to those in the first column of table 1. The unemployment rate has a strong positive effect on poverty, while the inflation rate has a negative, but statistically insignificant, effect.[21] Both inflation and unemployment significantly increase the JS poverty rate. In contrast to the findings of Blank and Blinder (1986) and Blank (1993) that inflation's effect is quite small relative to that of unemployment, the magnitude of the inflation effect on the JS poverty rate is nearly half that of the unemployment rate.

The second column includes real wages, as suggested by Mocan (1995), who argues that if wage gains cause inflation, the effect of inflation on poverty may be biased downward when this variable is excluded. However, the findings indicate that the estimated effect of inflation is robust with respect to the inclusion of real earnings. The third column includes demographic variables (for age, race, and family type) that

19 The model employs the same variables as Mocan (1995). It is noted below when the omission of variables from the models presented in table 1 affects the findings.

20 The income-poverty-rate errors appear to follow an autoregressive process of order one.

21 Trend variables for the post–1982 and post–1983 periods were insignificant in the differenced specification and were dropped.

may have affected the overall incidence of poverty. The demographic variables are jointly significant. In both the conventional and JS poverty-rate specifications, the estimated coefficients are robust with respect to the inclusion of demographic variables, although the importance of inflation relative to unemployment in explaining the JS poverty rate grows even more pronounced.[22] Due to the overstatement of inflation by the CPI-U and its possible contribution to overstating the conventional poverty rate, the alternative inflation rate based on the CPI-X1 was included, but the findings were not much affected.

Overall, unemployment seems to have a strong positive influence on both poverty rates, while inflation is only influential for the JS poverty rate. The finding that unemployment increases the JS poverty rate suggests that either structural (long-run) unemployment is affecting the lifetime incomes of the poor, or that cyclical unemployment imposes permanent income losses. While Mocan (1995) presents evidence that the influence of unemployment on conventional poverty rates is due to the adverse effects of long-run, not cyclical, unemployment, his findings are difficult to interpret, since the composition of the income poor is no doubt somewhat cyclical itself. In contrast, the estimated effects of inflation on the two poverty rates are dramatically different. Inflation has a marginally negative effect on the conventional poverty rate, but a fairly large positive effect on consumption poverty.

V. Conclusion

This paper has reexamined the empirical relationships between inflation, unemployment, and poverty, using a methodology similar to that of previous work that apparently had shown the importance of unemployment and unimportance of inflation in influencing poverty rates. I have demonstrated that these previous findings are sensitive to seemingly reasonable alternative poverty measures. The findings presented here suggest that although unemployment's effect on poverty rates is relatively robust with respect to the poverty concept, the effect of inflation on poverty may be more serious than previously thought.

How should these new findings influence thought about the role of monetary policy? For those who subscribe to the view that the monetary authority can lower or raise unemployment by enlarging or shrinking the money supply, the previous literature appeared to provide some evidence that expansionary monetary policy could make the average person better off by reducing unemployment, without the unpleasant side effect of making people worse off through inflation. The work presented here suggests that even if one accepts the existence of a trade-off between inflation and unemployment, one cannot be sanguine about the potential distributional costs of short-run stabilization policies, since the estimates are not robust with respect to alternative definitions of poverty.

In further research, it would be interesting to decompose inflation into its anticipated and unanticipated components, and unemployment into its cyclical and long-run components. Unanticipated inflation might have the most adverse effects on consumption poverty if people incorporate inflation expectations into their decisionmaking. It is also important to discover to what extent losses from transitory periods of high unemployment are made up in boom periods. Blank (1993) suggests that before the 1980s, low-income workers could make large real income gains during recoveries by increasing their hours of work. In a consumption poverty framework, one would expect the cyclical effects of unemployment to be mitigated to the extent that these earnings gains are anticipated. However, there may be penalties for discontinuity in labor-force participation, implying that even cyclical unemployment could affect permanent income.

It would be desirable to extend the data and analysis to examine the relationship between unemployment and inflation and the incidence of poverty within specific population subgroups. While the harmful impact of unemployment is still found to be larger than that of inflation when consumption-based poverty measures are used for the entire population, it would be interesting to discover whether this qualitative finding is uniform across households, or whether a very strong effect of inflation on some, but not all, groups is driving the findings.

Finally, the measurement of consumption poverty is a new and still controversial area. Based on their examinations of the CES samples (also used by Slesnick [1993]), Cutler and Katz (1991) conclude that "trends in the distribution of consumption closely mirror those in

22 The estimated coefficient of unemployment is highly sensitive to the inclusion of a government transfer variable in both the JS and conventional poverty specifications, suggesting that innovations in government policy and the prime-age-male unemployment rate are related.

the distribution of income" and that "while consumption poverty rates are below income poverty rates in every year, the time-series patterns for the two measures are quite similar." Applying the Census equivalence scales and conventional indexing to expenditure rather than income data, Slesnick finds the same pattern. It is his adjustment for the overstatement of inflation and his and Jorgenson's alternative equivalence scales that generate the very different findings.[23] Consequently, it is important to further explore the extent to which the findings presented here are driven by specific assumptions employed in the construction of Slesnick's consumption poverty rates.

Nevertheless, the findings of this new research into the relationship between inflation, unemployment, and poverty have called the robustness of the earlier findings into question. More research is needed before we can confidently say how macroeconomic developments affect poverty.

23 Interestingly, the Jorgenson–Slesnick equivalence scales assume smaller efficiency gains in consumption as family size increases than do the Census scales. Thus, Slesnick argues that the Census measure actually *understates* poverty in the 1960s and early 1970s.

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Scale Economies and Technological Change in Federal Reserve ACH Payment Processing

by Paul W. Bauer and Diana Hancock

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Introduction

Technological advances — accompanied by corresponding cultural changes and behavior adjustments — have had a tremendous influence on the array of payment instruments offered in the United States, on the diverse systems for processing them, and on their relative costs. Starting with the development of Magnetic Ink Character Recognition (MICR) in the 1950s, which facilitated the automation of check processing, the use of computers has transformed virtually every aspect of banking and the payments system.[1] For example, many new products, such as automated teller machines, point-of-sale terminals, touch-tone bill paying, and customer-initiated cash management services, are now widely available. Advances in computer technology—speed, storage, communications, and encryption capabilities—have meant faster, more accurate, more secure, and less costly back-office processing.

Since 1973, the use of electronic funds transfers has been accelerated by development of the automated clearinghouse (ACH). The ACH system, a nationwide, value-dated electronic funds transfer system typically used for recurring consumer and commercial payments, accommodates many types of transfers. The most common uses are to make utility, payroll, Social Security, tax, insurance premium, school tuition, mortgage, monthly investment, and dividend payments, and to manage business' cash concentration and disbursement activities.[2]

In the early 1980s, many observers argued that it would eventually become less expensive to transfer funds and settle most accounts electronically than to use traditional paper-based methods.[3] Consistent with those expectations, the Federal Reserve's direct and support costs for processing ACH payments today (approximately 1.4 cents per transaction) are less than

1 Payment data encoded at the bottom of checks have allowed high-speed check-sorting machines to process 80,000 to 100,000 checks per hour.

2 The National Automated Clearing House Association (1995) estimates that 42 percent of the private-sector workforce and 84 percent of government employees are paid using direct deposit. Also, more than 50 percent of Social Security recipients currently receive their benefits through direct deposit.

3 See, for example, Humphrey (1982, 1984, 1985).

for paper checks (about 2.5 cents per check).[4] Based on Federal Reserve data, the real unit cost (in 1994 dollars) of processing an ACH payment *fell* from 9.1 cents in 1979 to 1.4 cents in 1994. In contrast, the real unit cost of processing paper checks *rose* from 2.0 cents to 2.5 cents over the same period.[5]

Several hypotheses could account for the dramatic decline in both the absolute and the relative real costs of ACH processing. First, as the volume of ACH payments grew at double-digit rates, per-item costs may have dropped because processing sites were able to achieve greater scale efficiency. By their basic nature, telecommunication systems, which consist of communication equipment and circuits, offer significant economies of scale over wide ranges of output.[6] Such systems are one of the major inputs used in ACH payment processing. Early studies by Humphrey (1982, 1984, 1985), which used cross-sectional data from Federal Reserve ACH operations over the 1977–1982 period, verified that average ACH production costs fell as volume expanded. During that time, for each 1 percent rise in ACH processing volume, total production costs increased only 0.6 to 0.7 percent.

Second, technological change may have made it cheaper to provide ACH services. With the same quantities of inputs, more funds transfers could be processed. Software improvements, for example, could have resulted in fewer computing resources being used to process the same number of electronic payments.

Third, some of the major inputs used for electronic payment processing, including computers, experienced large quality-adjusted price declines during the 1980s. For the same cost, newer machines could process payments faster than their predecessors and could perform sophisticated tasks that were not previously feasible. Falling input prices would help to explain the absolute decline in real processing costs. At the same time, employee wages, paper costs, and other expenses associated with processing paper checks were generally rising.[7] The change in relative input prices would help to explain the decline in the relative real unit costs of ACH processing.

This study estimates the contribution of each of these factors—scale economies, technological change, and falling input prices—to the absolute reduction in the real processing cost of an ACH transfer. We use Federal Reserve data over the 1979–1994 period and various specifications for ACH cost functions.[8] Not surprisingly, we find that all three factors played a significant role. The split between cost savings attributed to scale economies (through volume growth) versus technological change depends on the specification chosen for the cost function. While scale economies accounted for a decline in unit costs on the order of 20 to 40 percent, technological change explained more than 30 percent. Cost savings attributed to input price reductions generally accounted for less than 10 percent of the real per-unit decline in ACH payment processing costs.

Our findings suggest that consolidating the Federal Reserve ACH processing sites will improve scale efficiency, further reducing processing costs. If recent experience is any guide, technological change will also present opportunities for further unit-cost declines. In addition, the marginal cost estimates presented in this study suggest that replacing paper checks with ACH transfers could enhance economic efficiency.

■ 4 Direct and support costs cover all expenses specifically attributable to providing Federal Reserve priced services, including labor, building, data processing, and data communication costs. They do not include allocations of overhead expenses, such as legal, accounting, and personal services, nor the Private-Sector Adjustment Factor (PSAF), which takes into account the taxes that would have been paid and the return on capital that would have been provided had the services been performed by a private firm. Further, this definition of direct and support costs does not include the costs to payors and payees of processing payments. Thus, the Federal Reserve's costs are only a portion of the social costs of providing payment services.

■ 5 The real unit costs of processing ACH transfers and checks are calculated using the implicit GDP price deflator for 1979 and 1994.

■ 6 Scale economies were first studied in industries employing pipelines and boilers. There is a clear mathematical reason for this. Expanding the diameter of a pipe increases the amount of material required to manufacture it by only two-thirds as much as its capacity. (See, for example, Berndt [1991].) Similarly, in the context of communication systems, laying a fiber-optic line is not much costlier than laying a copper wire, but the former has many times the carrying capacity.

■ 7 Per-item wages have fallen over time because of capital improvements.

■ 8 The cost function is the minimum cost of producing any specified level of output given technological constraints and input prices.

FIGURE 1

Unit Costs (1994 dollars)

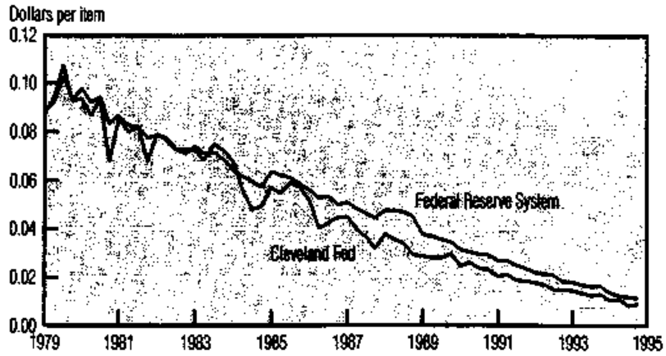


FIGURE 2

ACH Processing Volume

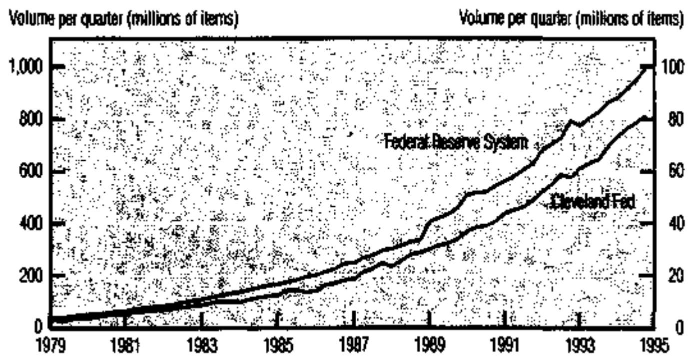
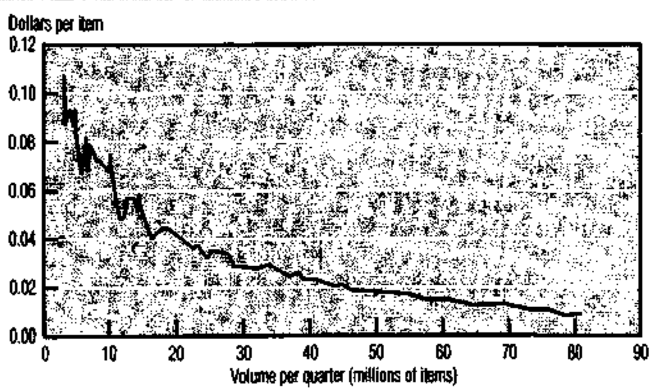


FIGURE 3

Real Unit Costs vs. ACH Processing Volume for the Cleveland Fed, 1979–1994 (1994 dollars)



SOURCE: Authors' calculations.

I. What Is an ACH Transfer?

The ACH system is a value-dated electronic funds transfer system. The principal participants in an ACH transaction are the payor, the payee, the payor's bank, the payee's bank, and the ACH operator.[9] Either credit transfers or debit transfers may be made using an ACH system. With credit transfers, such as direct payroll deposits, the payor's bank typically initiates the transfer, and funds flow from the payor's bank to the payee's bank. With debit transfers, such as mortgage payments, the payee's bank initiates the transfer and receives funds from the payor's bank.

ACH transactions offer several key advantages over paper instruments. First, in most cases, payors know exactly when the funds will be removed from their accounts, and payees know exactly when the funds will be deposited to their accounts. Second, particularly for consumer bill payments, ACH transactions may be convenient because the payor does not have to remember to write and deliver a paper check, and the payee does not have to cash or deposit it. Third, the total costs to all parties are much lower for ACH transactions than for paper checks.[10] Finally, accounting efficiencies may exist for business payors and payees who have implemented electronic data interchange to facilitate communications with trading partners.[11]

II. A Look at the Raw Data

Before presenting statistical measures of scale economies and technological change, it is instructive to look at the raw data to determine how Federal Reserve ACH processing costs have varied over time and with different volume levels. Figure 1 presents unit costs (in 1994 dollars) over the 1979–1994 period, using

9 We use the term "bank" to refer to all depository institutions.

10 The full social cost of processing an ACH item is only about a third to a half as much as for a check (see Humphrey and Berger [1990] and Wells [1994]).

11 See Knudson, Walton, and Young (1994) for a discussion of the potential benefits of financial electronic data interchange (a combination of electronic remittance data and electronic funds transfers) for business payments.

processing volumes as the measure of output.[12] Despite improvements in the ACH service—including the introduction of encryption, increased use of backup facilities, more deliveries per day, a wider variety of formats, provisions allowing more information to be supplied with the payment, and conversion to an all-electronic ACH environment—Federal Reserve per-unit costs have fallen steadily. Similar declines are observed at each processing site. For example, the Cleveland District's unit-cost decline paralleled that of the System as a whole. This suggests that technological change could have been the dominant factor driving down ACH processing costs. However, output volume and input prices did not remain constant.

Between 1979 and 1994, total ACH processing volume at the Federal Reserve grew at an average annual rate of more than 22 percent (see figure 2), reaching 2.4 billion payments valued at $8.4 trillion by the end of 1994.[13] If scale economies exist, then volume growth of this magnitude could account for a large share of the decline in unit costs.

Figure 3 plots the unit cost per ACH transfer processed in the Cleveland Federal Reserve District against the number of quarterly transfers processed at that site over the 1979–1994 period. Note that unit costs fell fairly steadily as volume increased. The experience at other Federal Reserve ACH processing sites was similar. Figure 3 suggests that scale economies (resulting from increased volume) were the dominant factor pushing down ACH processing costs. In general, however, output, technology, and input prices were all fluctuating (in some cases dramatically) over this period, necessitating a multivariate approach to data analysis to investigate changes in ACH costs. Both the formulation of public policies for electronic payments and the appropriate pricing framework for such payments hinge on an accurate understanding of the different sources of real unit-cost reductions.

In general, the cost-function approach we employ in this paper is well suited to handling the contemporaneous effects of scale economies, as well as technological change and other factors. Unfortunately, the Federal Reserve's ACH data for each processing site show a strong correlation (greater than 99 percent) between the number of items processed (output) and a time trend (a technology index that is commonly used when a better measure is lacking). With such a high degree of correlation, it is difficult to disentangle the effects of technological change (the time trend) from those of scale economies (volume growth).

From a technical standpoint, econometric models that include two highly correlated variables have upwardly biased standard errors, making it difficult to obtain precise estimates of the model's parameters. Also, the cost-function coefficient estimates could be sensitive to small changes in the model's specification.

Since there is reason to believe that both scale economies and technological change are important factors in the real unit-cost decline for ACH processing, we choose to test for model robustness by trying alternative specifications for the cost function (for example, employing yearly indicators instead of a time trend to allow for technological change). We also use different sample periods within our pooled cross-section and time-series samples.

III. Estimation

To determine the effects of scale economies, technological change, and falling input prices on ACH processing costs, we estimate a cost function using quarterly cost data for Federal Reserve processing sites. This function maps the best (least-cost) method of processing each level of transfers when inputs, such as labor and computers, can be varied freely. In general, the least costly production method depends on the scale of operations. The cost function is a useful concept for our purposes, because many characteristics of technology can be derived from it, such as estimates of scale economies, marginal costs, and technological change (as will be explained more fully below).

We employ the translog cost function because it provides a good local approximation of any arbitrary twice-differentiable cost function. Thus, the translog function can model many

■ 12 Throughout this paper, payments initiated and received at a processing site are counted once. Payments received and partially processed at one site and then transmitted and processed again at another are counted at both the sending and receiving sites. Therefore, processing volumes exceed the number of ACH payments made.

■ 13 A National Automated Clearing House Association press release dated March 27, 1995 ("ACH Statistics Fact Sheet") estimates that the total volume of payments handled by ACH processors (including the Federal Reserve) was 2.5 billion, valued at $10.1 trillion, in 1994. These statistics exclude estimated "on-us" items (wherein the payor and payee accounts are held at the same bank and consequently do not require external processing). Although the growth rate and volume of ACH payments may seem impressive, these payments accounted for fewer than 4 percent of all noncash transactions processed domestically and only about 1 percent of the dollars exchanged in 1994.

different possible relationships among the number of transfers processed (outputs), inputs, and environmental factors, depending on its parameter values. Our general translog cost function can be written as

$$(1)\quad \ln C_{it} = \beta_0 + \beta_y \ln y_{it} + 1/2\, \beta_{yy} (\ln y_{it})^2 + \sum_{k=1}^{K} \gamma_k \ln w_{kit} + 1/2 \sum_{k=1}^{K} \sum_{j=1}^{K} \delta_{kj} \ln w_{kit} \ln w_{jit} + \sum_{k=1}^{K} \delta_{yk} \ln y_{it} \ln w_{kit} + \sum_{m=1}^{M} \lambda_m Z_{mit} + \sum_{j=1980}^{1994} \Phi_j YR_j + \sum_{j=2}^{12} \xi_j D_j + v_{it},$$

where y_{it} is the number of ACH items processed at site i in period t, w_{it} is a vector of K input prices for site i in period t, Z_{it} is a vector of M environmental variables for site i in period t, D_j (j=2,...,12) is a set of site indicator variables (one for every processing site),[14] YR_j (j=1980,...,1994) is a set of T–1 yearly indicator variables (one for every year except the first), and v represents the error term.[15] In some specifications, we use the time-trend term T = 1,...,N, and its squared term, T^2, instead of the yearly indicator variables, YR_j, to represent technological change.

Depending on the model specification and the sample period selected, we set some of the coefficients of the translog cost function equal to zero. Several specifications of the cost function are estimated using ordinary least squares (OLS), and we denote these models as OLS Models 1 and 2. These elementary cost functions include only an intercept, the log of the number of items processed at each site, yearly indicators or a time-trend variable, and, in the case of OLS Model 2, some environmental variables. OLS Model 2 is similar to the cost function estimated by Humphrey (1982, 1984, 1985) for the ACH service.

In our most sophisticated specification, we estimate the translog specification of the cost function jointly with the input share equations derived using Shephard's Lemma.[16] Estimation of both the cost function and the input share equations provides additional degrees of freedom and statistical precision. The system of cost and share equations is estimated using the iterative seemingly unrelated regression (ITSUR) technique.[17] We denote these models as ITSUR Models 1 and 2. ITSUR Model 1 does not include site indicator variables (D_j), in effect forcing the coefficients ξ_j (j = 2,...,13) to equal zero. For both ITSUR models, we estimate equation (1), along with the corresponding equations for input shares, imposing the usual mathematical restrictions of symmetry and linear homogeneity in input prices. These restrictions, derived from economic theory, reduce the number of cost-function parameters that need to be estimated and thereby increase the number of degrees of freedom available. Symmetry restrictions follow from assuming that the cost function is twice differentiable in input prices, or

$$(2)\quad \frac{\partial^2 C}{\partial w_k \partial w_j} = \frac{\partial^2 C}{\partial w_j \partial w_k}.$$

This forces $\delta_{kj} = \delta_{jk}$ for every k and j. Linear homogeneity in input prices means that only relative input prices matter. That is, proportional changes in input prices affect only the level of cost, not the cost-minimizing set of inputs.[18] Linear homogeneity restrictions result from defining the cost function as yielding the minimum cost of producing a given output level when faced with a particular set of input prices. In order to impose linear homogeneity, the following parameters related to the $\ln w_{kit}$'s are restricted such that

$$(3)\quad \sum_k \gamma_k = 1 \text{ and } \sum_k \theta_{yk} = \sum_k \delta_{kl} = 0.$$

IV. Decomposition of Cost Savings over Time

For a particular site, one could examine the ratio of unit costs in two periods. Although this ratio would show whether unit costs had risen or fallen, it would not indicate whether the shift

■ 14 The first processing site is the base against which the others are measured. Consequently, it does not have a site indicator variable. The choice of the base site does not affect our final results.

■ 15 The number of yearly indicator variables, YR_j, depends on how many years of data are included in the sample.

■ 16 See Diewert (1982) for a discussion of Shephard's Lemma.

■ 17 See Bauer and Hancock (1993) for a look at the various econometric techniques that can be used to estimate a system of cost and share equations.

■ 18 Mathematically, linear homogeneity can be expressed as $\lambda C(y, w) = C(y, \lambda w)$, where λ is greater than zero ($\lambda = 2$ if input prices double).

stemmed from scale economies, input price differences, environmental differences, or technological change. To decompose the movements in unit costs attributable to various factors across time using cost-function (1), we can rewrite the ratio of a site's current unit costs (with the period denoted by subscript S) to that of the first period (with the period denoted by subscript O) as follows:[19]

$$(4)\quad \ln\left[\frac{(C_{iS}/y_{iS})}{(C_{iO}/y_{iO})}\right]$$

$$= \ln\left[\frac{C(y_{iS}, w_{iS}, z_{iS})\exp(\epsilon_{iS})}{y_{iS}}\right]$$

$$- \ln\left[\frac{C(y_{iO}, w_{iO}, z_{iO})\exp(\epsilon_{iO})}{y_{iO}}\right].$$

Using the cost function defined in equation (1) and recalling that the log of a ratio is equal to the difference of the log of the numerator minus the log of the denominator, the percentage change in unit costs between periods, S and O, or equation (4), can be rearranged into the following expression:

$$(5)\quad \ln\left[\frac{(C_{iS}/y_{iS})}{(C_{iO}/y_{iO})}\right] = \left[\Phi_S - \Phi_O\right]$$

$$\left[\beta_y(\ln y_{iS} - \ln y_{iO})\right.$$

$$+ 1/2\,\beta_{yy}(\ln y_{iS}^2 - \ln y_{iO}^2)$$

$$\left. - (\ln y_{iS} - \ln y_{iO})\right]$$

$$+ \left[\sum_{k=1}^{K} \gamma_k(\ln w_{kS} - \ln w_{kO})\right.$$

$$+ 1/2\sum_{k=1}^{K}\sum_{j=1}^{K}\delta_{kj}(\ln w_{kiS}\ln w_{kjS}$$

$$\left. - \ln w_{kiO}\ln w_{kjO})\right]$$

$$+ \left[\sum_{k=1}^{K}\theta_k(\ln y_{iS}\ln w_{kiS} - \ln y_{iO}\ln w_{kiO})\right]$$

$$+ \left[\sum_{m=1}^{M}\lambda_m(\ln Z_{miS} - \ln Z_{miO})\right]$$

$$+ \left[\epsilon_{iS} - \epsilon_{iO}\right],$$

where the bracketed terms are defined as the technological change effects, scale effects (different processing volumes), input price effects (different input prices), interaction effects between processing volumes and input prices, environmental effects, and a random effect.[20, 21] Although these terms are in logarithmic differences, they can be roughly interpreted as the percentage difference in costs stemming from the various effects.[22] Equation (5) provides a convenient framework for quantifying the source of cost savings over time.

V. Data Construction

We collected quarterly data from 1979 to 1994 on total costs, ACH processing volumes, input prices, and environmental variables for Federal Reserve ACH processing sites. During the 1979–1989 period, the number of these sites fell from 38 to 21. By an overwhelming margin, the largest volumes were handled by the 12 Reserve Banks and the Los Angeles branch of the San Francisco Fed. By 1993, only the 12 main Reserve Bank offices were still processing ACH items. Consequently, we aggregated the data at the District level, with the exception of the Los Angeles facility, which we treated as a separate site. The New York Fed was omitted from the estimations because most of the commercial ACH volume in its region was processed by the New York Automated Clearing House.

Our primary data source is quarterly cost accounting reports prepared by the Federal Reserve in its Planning and Control System (PACS). This information is supplemented by other cost and revenue data, results from occasional Federal Reserve surveys, and price index figures from the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics.

Production costs for processed ACH transactions are included in our calculations, but

■ 19 Any two periods could be chosen to compare unit costs, but comparing the first to the last is likely to be the most informative.

■ 20 This decomposition uses the same methodology employed in Bauer (1993) to study differences in unit costs across Federal Reserve check-processing sites.

■ 21 The interaction effect is a collection of terms that cannot be classified cleanly into any of the other categories. Fortunately, the magnitude of this effect tends to be small.

■ 22 For the exact percentage difference, the antilog of each expression minus one should be used. We report the exact percentage differences of our results in table 5.

TABLE 1

Average Input Cost Shares, 1989–1994 (percent)

Input Classification	Cost Shares
Labor	21.3
Materials	40.6
Communications	35.6
Building	2.5

SOURCE: Authors' calculations.

imputed costs and certain overhead expenses, such as accounting costs and special District projects, are not. For the output measure, we use site-specific figures that focus on transactions processed at a site, rather than the number of payments (see footnote 12).

Labor, material, communication, and building costs are inputs for ACH processing. The shares of direct and support costs for each of these factors over the 1989–1994 period are reported in table 1.[23] Labor expenditures include salaries, retirement, and other benefits. The price of labor is total labor expenditures divided by the number of employee hours spent processing ACH transactions.

While buildings' share of costs is small, the interest expenses associated with the acquisition of fixed assets are not represented in the cost-accounting framework (these are included in the inputed costs [PSAF] rather than in direct and support costs). Cost accounting information is supplemented by annual replacement-cost indexes for each site, available from the R.S. Means Company.[24] Square-foot replacement costs, adjusted by the depreciation rate, are used to calculate maintenance and building prices for each site.

Expenditures for materials are composed of outlays for office equipment and supplies, printing and duplicating, and data processing. The service price for materials is constructed by supplementing cost-accounting expenditure data with indexes for information and processing equipment.[25] For computer hardware, an estimate of the service value, or price, of machines is constructed using formulas that employ a perpetual inventory model.[26] For data system support services, which are primarily used for in-house, product-specific software development, we construct a price by utilizing expenditures for labor and hours worked in that area of each Reserve Bank. For the service price of supplies (printing and duplicating, office supplies, and office equipment), we use the GDP implicit price deflator. We apply index number theory to construct a price index for materials that uses expenditures and prices for the components of materials—data processing, data systems support, and office supplies and equipment.

Communications expenditures comprise the expenses associated with data and other communications, shipping, and travel. The implicit price deflator for communications equipment purchases by nonresidential producers is used for data and other communications. The fixed-weight aircraft price index for private purchases of producers' durable equipment is employed for shipping and travel expenditures. Using index number theory, we calculate an overall price index for communications using the expenditure shares of two categories of communications (communications and shipping) and their individual price indexes.

Environmental variables that may affect ACH processing costs are the proportion of federal government items in the processing stream, the number of banks served by a processing site, and the proportion of banks receiving electronic payment information. On one hand, government items may be less expensive to process because the Federal Reserve has more discretion over file-processing times for these items than for commercial items. On the other hand, government items could be more expensive to process than commercial items because they are concentrated over short periods during the month and thus may drive processing capacity needs. The number of endpoints is the number of banks or processors to which ACH payments

■ 23 We focus on this period for several reasons. First, all of the data series are complete. Second, in the early period, full-cost pricing (required by the Monetary Control Act of 1980) was gradually introduced. Third, consolidation of processing sites could cloud the effects of scale economies in the early period. Consolidation effects are likely to be of minor significance, however, because of the low processing volumes and costs incurred at the additional sites. Finally, such dramatic technological changes occurred that a single cost function may be unable to fit the entire sample period adequately. Consequently, by concentrating on the most recent data, we should get the best estimates of the current cost function for ACH processing.

■ 24 Data on replacement costs for buildings are taken from Means (1994).

■ 25 The BEA's implicit price deflator for information processing and related equipment is used for data processing and computer hardware.

■ 26 These formulas were derived by Hall and Jorgenson (1967).

TABLE 2

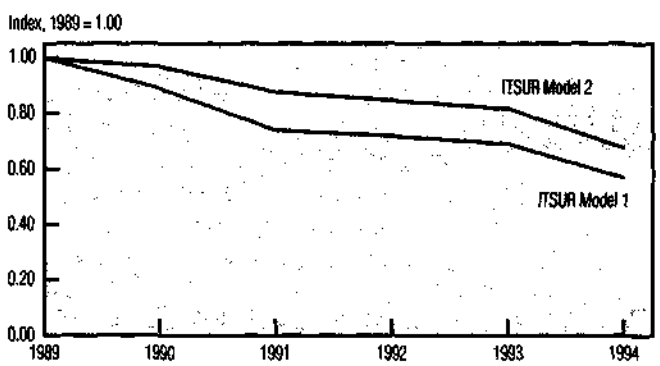
Technological Change Indexes (1989 = 1.000)

Year	ITSUR Model 1	ITSUR Model 2
1989	1.000	1.000
1990	0.889	0.973
1991	0.739	0.876
1992	0.716	0.847
1993	0.691	0.818
1994	0.568	0.676

SOURCE: Authors' calculations.

FIGURE 4

Technological Change Indexes



SOURCE: Authors' calculations.

information is delivered. Nonelectronic deliveries by computer tapes, diskettes, and paper methods increase transportation costs.[27] In contrast, using electronic networks for deliveries may create greater scale efficiencies.

VI. Empirical Results

We estimated cost functions with and without the data for the early (1979–1988) period both to provide a historical perspective and to ease comparison with previous studies. The empirical results for the OLS cost-function models are reported in the appendix. Estimates from these models demonstrate that our qualitative findings are robust to changes in the assumptions employed in the estimation and in the sample period selected. In the body of the paper, we focus on the two ITSUR models estimated using data from 1989 to 1994. It is only during this period that data on the number of endpoints with electronic connections are available. Another reason we concentrate on the more recent period is that the methods used for ACH processing have changed dramatically over time. In the earlier period, ACH transaction data were delivered to the Federal Reserve Banks on computer tapes, and the Fed delivered data to receiving institutions on both computer tapes and paper listings. In the more recent period, however, ACH processing has essentially become a computer network-based system. We are interested in whether different technologies for transmitting ACH transfers yield strikingly different estimates for scale economies and for technological change. Therefore, we estimate the cost function for the latest period possible —subject to the constraint of having sufficient degrees of freedom to estimate the model with statistical precision.

ITSUR Models 1 and 2 estimate the cost function jointly with three of the four input share equations using the ITSUR technique. These models are preferred because they allow for a fuller complement of regressors and because including the cost-share equations increases statistical precision. ITSUR Model 2 differs from ITSUR Model 1 in that it includes processing-site indicator variables that allow for site-specific conditions not otherwise controlled for.

Technological Change

Table 2 presents estimates of technological change obtained from the two models above. The technological change index is set equal to one in 1989, with numbers below that indicating technological advance over the base year. For example, ITSUR Model 1's 1994 index indicates that unit costs are only 56.8 percent of costs in 1989, other things held constant. ITSUR Model 2 finds somewhat less technological change, with 1994 costs only 67.6 percent of those incurred in 1989. For ITSUR Model 1, this works out to a technological change estimate of more than 10 percent per year from 1989 to 1994. Inclusion of processing-site-specific intercepts (ITSUR Model 2) lowers the estimate to just over 7.5 percent per year—still a rather hefty reduction. While the estimates of technological change differ, both models find the same pattern of unit-cost declines (see figure 4).

27 All ACH transactions were delivered electronically as of July 1, 1993 for the commercial (non-federal government) sector and as of July 1, 1994 for the federal government sector.

TABLE 3

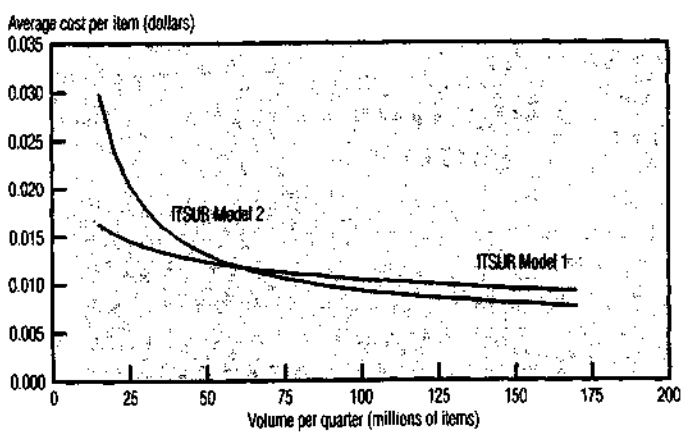
Cost Elasticity Estimates

Federal Reserve ACH Processing Site	ITSUR Model 1		ITSUR Model 2	
	1989	1994	1989	1994
1	0.756	0.764	0.413	0.587
2	0.766	0.776	0.280	0.444
3	0.754	0.761	0.449	0.661
4	0.760	0.771	0.328	0.550
5	0.760	0.766	0.301	0.486
6	0.756	0.763	0.390	0.566
7	0.758	0.760	0.256	0.487
8	0.761	0.768	0.192	0.442
9	0.758	0.765	0.381	0.583
10	0.761	0.761	0.349	0.624
11	0.763	0.772	0.212	0.419

SOURCE: Authors' calculations.

FIGURE 5

Estimated Average Cost Functions



SOURCE: Authors' calculations.

Scale Economies

Cost elasticities measure the effect of a one-percentage-point increase in output on total cost. For example, a cost elasticity of 0.75 means that if output increases 1 percent, costs would rise only 0.75 percent. A cost elasticity of less than one indicates the existence of scale economies (that is, average cost falls as output increases). Alternatively, a cost elasticity greater than one indicates the existence of scale diseconomies (average cost rises as output increases).

Although still finding significant scale economies during the 1989–1994 period, ITSUR Models 1 and 2 provide estimates of cost elasticities of widely different magnitudes. Table 3 presents cost elasticity estimates for each of the processing sites that remained in operation for the entire sample period, using their mean processing volume levels for 1989 and 1994. ITSUR Model 2 provides greater estimates of scale economies for all sites than does ITSUR Model 1. To understand why, consider figure 5, which plots the estimated average cost curves using both models. To the naked eye, these curves appear to be reasonably similar. In ITSUR Model 1, however, the coefficient of the squared term for the number of items processed is close to zero and is statistically insignificant. Based on this model, the cost elasticity is essentially constant at around 0.75 throughout the full range of observed output, implying that scale economies are never exhausted. In contrast, for ITSUR Model 2, the squared term for the number of items processed is positive and statistically significant. This means that the cost elasticity varies along with the number of items processed. Consequently, ITSUR Model 2 suggests that scale economies will eventually be exhausted (that is, the average cost curve will eventually begin to rise).

The volume level at which scale economies are exhausted is important, because it helps to determine whether consolidating the Federal Reserve processing sites could lower unit costs. Scale economies are exhausted when the cost elasticity equals one. By setting the cost elasticity equal to one, we can solve for the implied number of items processed by a site operating at an efficient scale. Using this procedure and ITSUR Model 2, an estimate of about 800 million items processed per quarter for a scale-efficient site is implied. This is more than five times the quarterly processing volume of the largest Federal Reserve site observed in our sample (144 million items per quarter).

For both ITSUR models, estimates of the volume level at which scale economies are exhausted need to be viewed with a fair degree of skepticism. Recall that the translog cost function is a good local approximation of the cost function and is therefore quite reliable in studying output ranges actually observed in the data. While both models find significant scale economies in the current range of output, going beyond this range is highly speculative.

TABLE 4

Marginal Cost Estimates (dollars per item)

Federal Reserve ACH Processing Site	ITSUR Model 1 1989	ITSUR Model 1 1994	ITSUR Model 2 1989	ITSUR Model 2 1994
1	0.0204	0.0095	0.0112	0.0073
2	0.0215	0.0095	0.0079	0.0054
3	0.0233	0.0087	0.0139	0.0076
4	0.0182	0.0068	0.0078	0.0049
5	0.0269	0.0135	0.0107	0.0086
6	0.0204	0.0056	0.0105	0.0042
7	0.0321	0.0085	0.0109	0.0054
8	0.0215	0.0069	0.0054	0.0040
9	0.0205	0.0064	0.0103	0.0048
10	0.0262	0.0076	0.0120	0.0062
11	0.0361	0.0110	0.0101	0.0060
Volume-weighted System average	0.0234	0.0083	0.0106	0.0060

SOURCE: Authors' calculations.

The presence of scale economies implies that scale efficiency could be improved by consolidating the Federal Reserve ACH processing sites. Indeed, the Fed is currently consolidating its ACH operations at one computing site with backup facilities at another. Our empirical results suggest that these efforts will reduce average processing costs significantly. Comparing the average ACH processing cost at the current largest site with a forecasted average cost for a consolidated site handling all currently processed ACH items, the predicted average decline is 30 percent and 25 percent for ITSUR Models 1 and 2, respectively.[28] Neither model predicts that scale economies would be exhausted with one processing site, but ITSUR Model 2 predicts that further scale efficiencies from additional volume growth could be quite small.

Pricing

The Monetary Control Act of 1980 directs the Federal Reserve to establish fees on the basis of all direct and indirect costs incurred in providing payment services, including "interest on items credited prior to actual collection, overhead, and an allocation of imputed costs which takes into account the taxes that would have been paid and the return on capital that would have been provided had the services been provided by a private business firm." Thus, the total revenues raised from providing payment services must match the total costs incurred in production.

Generally, allocations of goods and services are most efficient when prices (the amount a consumer must pay to receive one unit of the good) are set equal to marginal costs (the additional cost of producing one more unit of output).[29] With scale economies of the magnitude we have found for ACH transactions, marginal cost pricing alone would not generate sufficient revenue to cover costs. The reason is that the presence of scale economies means unit costs fall as additional units are produced, and this can occur only if marginal costs are lower than average costs. The current Federal Reserve fee structure for the ACH service solves this problem by employing a multipart structure with both fixed and variable components.[30] Ideally, to encourage greater use of electronic payments, the variable fee should be set equal to marginal costs and the fixed fees set to make up the shortfall.

Our estimates of marginal costs, calculated using the two ITSUR models, are presented in table 4. Consistent with its finding of larger scale economies, ITSUR Model 2 generates lower marginal cost estimates than does ITSUR Model 1. Marginal costs for ITSUR Model 1 range from \$0.0056 to \$0.0135 per item in 1994, with a volume-weighted System average of \$0.0083. ITSUR Model 2's marginal costs are all estimated to be under \$0.01 per item in 1994, with a volume-weighted System average of \$0.006.

Sources of Cost Savings

In table 5, we use equation (5) to decompose unit-cost declines over the 1989–1994 period into technological change effects, scale economy effects, input price effects, environmental

■ 28 Note that with full consolidation, the number of items processed will equal the number of payments processed, approximately 600 million items per quarter.

■ 29 Mathematically, marginal cost (MC), the change in costs resulting from a unit increase in output, is defined as $MC = \partial C/\partial y$.

■ 30 See Baumol and Bradford (1970), Oi (1971), Roberts (1979), Humphrey (1984), Sheshinski (1986), Brown and Sibley (1986), Hirshleifer and Glazer (1992), and Tirole (1994) for discussions about efficient pricing methods when there are positive scale economies for an industry's output level.

TABLE 5

Sources of Cost Savings

ITSUR Model 1

Federal Reserve ACH Processing Site	Unit Cost[a] 1989	Unit Cost[a] 1994	Overall Percentage Change	Technological Change Effects	Scale Economy Effects	Input Price Effects	Environmental Effects	Interaction Effects
1	0.027	0.012	−53.9	−43.2	−16.9	−5.8	0.1	0.5
2	0.028	0.012	−56.5	−43.2	−16.2	−8.3	−22.0	−0.3
3	0.031	0.011	−63.0	−43.2	−20.2	−6.0	−5.3	1.0
4	0.024	0.009	−62.9	−43.2	−21.2	−14.1	−5.7	0.3
5	0.035	0.018	−50.1	−43.2	−18.4	−9.8	−5.8	−0.4
6	0.027	0.007	−72.7	−43.2	−17.2	−9.2	8.1	0.2
7	0.042	0.011	−73.7	−43.2	−23.0	−6.5	2.5	−1.0
8	0.028	0.009	−68.1	−43.2	−24.6	−8.1	−28.3	−1.4
9	0.027	0.008	−69.3	−43.2	−19.6	−8.8	−0.8	0.5
10	0.034	0.010	−71.0	−43.2	−26.5	−4.0	1.3	0.5
11	0.047	0.014	−69.8	−43.2	−20.4	−5.3	−0.5	−1.1

ITSUR Model 2

Federal Reserve ACH Processing Site	Unit Cost[a] 1989	Unit Cost[a] 1994	Overall Percentage Change	Technological Change Effects	Scale Economy Effects	Input Price Effects	Environmental Effects	Interaction Effects
1	0.027	0.012	−53.9	−32.4	−37.5	−5.9	0.8	0.6
2	0.028	0.012	−56.5	−32.4	−28.3	−8.3	13.7	−0.4
3	0.031	0.011	−63.0	−32.4	−46.8	−6.0	0.8	1.1
4	0.024	0.009	−62.9	−32.4	−41.4	−14.1	4.2	0.3
5	0.035	0.018	−50.1	−32.4	−34.2	−9.8	1.8	−0.4
6	0.027	0.007	−72.7	−32.4	−36.9	−9.2	−1.1	0.3
7	0.042	0.011	−73.7	−32.4	−40.5	−6.4	1.8	−1.0
8	0.028	0.009	−68.1	−32.4	−38.5	−8.0	18.9	−1.5
9	0.027	0.008	−69.3	−32.4	−41.3	−8.9	2.3	0.6
10	0.034	0.010	−71.0	−32.4	−53.3	−4.0	0.1	0.5
11	0.047	0.014	−69.8	−32.4	−32.2	−5.2	2.5	−1.1

a. In dollars.
SOURCE: Authors' calculations.

effects, and interaction effects. For each of the processing sites, unit costs fell precipitously. ITSUR Model 1 attributes the bulk of the decline, 43.2 percent, to technological change, versus only 32.4 percent for ITSUR Model 2. In contrast, ITSUR Model 2 finds larger cost savings due to scale economies than does ITSUR Model 1.

Falling input prices—mainly for data communications and data processing—generally account for less than 10 percent of the savings. As described in section V, we rely on the BEA's price indexes to help construct our measure of materials, which includes information-processing and related equipment. The quality of such equipment changed rapidly during the 1980s and 1990s. Thus, to the extent that the price series for materials do not adequately control for the qualitative changes in these inputs, our decomposition of cost savings resulting from technological change may be overstated, while cost savings resulting from input price reductions may be understated. To some degree, the distinction is arbitrary. The decline in ACH costs may stem from technological change within ACH payments processing itself or from technological change in the computer industry that has lowered input prices. In either case, reduced costs from technological change are not misattributed to scale economies.

Environmental and interaction-term effects tend to be relatively small, except for two sites, and these sites have by far the fewest number of endpoints. ITSUR Model 1 attributes their lower costs (other things held constant) only to this factor. ITSUR Model 2, however, also allows for a different intercept term for these sites and finds smaller District indicator variable coefficients, suggesting that some other site-related factor is at work.

VII. Conclusion

We employ a cost-function model of ACH processing to derive estimates of both scale economies and technological change from 1979 to 1994. Substantial and statistically significant scale economies are found to exist at all Federal Reserve processing sites. For example, using cost system models, we estimate that for each 10 percent increase in ACH processing volume, total production costs rose by less than 8 percent, indicating that average costs fall as volume rises. Therefore, consolidating the System's processing sites should reduce ACH processing costs substantially in the long run. In addition, given the potential scale economies for electronic payments processing and the low marginal costs, more attention is warranted for demand-side issues that would encourage payors to shift from paper checks to ACH transactions.

More than 30 percent of the decline in real unit costs between 1989 and 1994 can be attributed to technological change, with an annual rate of change of at least 7.5 percent. Scale economies led to a further 20 to 40 percent reduction. Another significant contributing factor to the decline in unit costs was lower input prices (primarily for communications and computing technology), which translated into a cost savings of about 8 percent between 1989 and 1994.

In the 1980s, some observers believed that scale economies would eventually push the interbank unit costs of processing ACH transactions below those of processing paper checks.[31] Our findings suggest that their expectations were correct. In addition, technological change and lower prices for communications and computing technology have also played a major role.

Clearly, more empirical research is needed on how new technologies affect the efficiency of the payments system. For example, scope economies between ACH payment processing and other payment processing, such as Fedwire and paper-based checks, could also be important in determining the scale efficiency and optimal product mix for payment service providers. Such scope economies could enable many more suppliers to operate efficiently and to reduce the real resource costs associated with processing payments. Finally, in order to construct a pricing mechanism that encourages efficiency in the payments system and yet still recovers costs, the demand side of payment service markets—including cross-elasticities between payments instruments—needs to be more fully understood.

Appendix: Sensitivity Analysis

The strong correlation between the number of ACH items processed and the time-trend variable makes it difficult to separate the effects of scale economies and technological change. Thus, we estimate equation (1) in several different ways in order to determine the robustness of our qualitative findings of significant scale economies and technological change. First, we measure technological change either with a smooth time trend or with discrete yearly indicator variables. Second, we estimate the model using data from the entire sample period, from each year separately, and from the 1989–1994 period only.

OLS Model 1 is the most basic cost-function specification. Costs are regressed against the output measure (number of items processed) and against quarterly indicator variables. Models indicated by an *a* use yearly indicator variables to measure technological change, while models indicated by a *b* use a time trend and its squared term. OLS Model 2 is similar to OLS Model 1, except that control variables for the price of labor, the number of endpoints, and the percentage of government items are also included. Model 2 is also similar to those estimated by Humphrey (1982, 1984, 1985). A squared term for output is not included because the high correlation between the time-trend variable and output implies that the square of the latter could not be adequately handled in a single-equation setting. Below, we briefly summarize the findings of these OLS estimations and compare them to the two ITSUR models presented in the body of the paper.

■ 31 For example, see Humphrey (1982, 1984, 1985) and Zimmerman (1981).

TABLE A-1

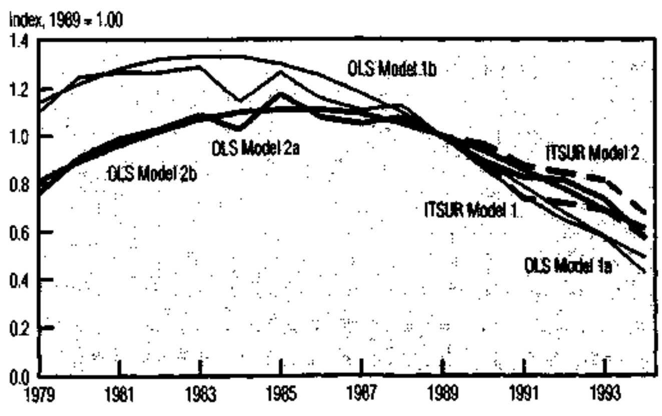
Technological Change Indexes (1989 = 1.000)

Year	OLS Model 1a	OLS Model 1b	OLS Model 2a	OLS Model 2b	OLS Model 1a	OLS Model 1b	OLS Model 2a	OLS Model 2b	ITSUR Model 1	ITSUR Model 2
1979	1.097	1.139	0.764	0.809						
1980	1.248	1.217	0.914	0.888						
1981	1.266	1.277	0.991	0.960						
1982	1.272	1.317	1.034	1.020						
1983	1.287	1.335	1.090	1.067						
1984	1.154	1.329	1.027	1.099						
1985	1.271	1.300	1.179	1.114						
1986	1.156	1.250	1.079	1.110						
1987	1.105	1.181	1.045	1.090						
1988	1.127	1.096	1.083	1.052						
1989	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1990	0.869	0.896	0.905	0.935	0.875	0.900	0.890	0.919	0.889	0.973
1991	0.753	0.789	0.829	0.861	0.763	0.791	0.777	0.822	0.739	0.876
1992	0.645	0.683	0.815	0.780	0.658	0.679	0.732	0.717	0.716	0.847
1993	0.581	0.581	0.744	0.695	0.596	0.569	0.638	0.609	0.691	0.818
1994	0.428	0.485	0.579	0.610	0.441	0.465	0.482	0.503	0.568	0.676

SOURCE: Authors' calculations.

FIGURE A-1

Technological Change Indexes



SOURCE: Authors' calculations.

Technological Change

Estimates of technological change for all models are reported in table A-1 and plotted in figure A-1. To ease comparison, all of the technological change indexes are normalized to equal one in 1989. Whether yearly indicator variables or a time trend and its squared term are used to measure technological change, the technological indexes are similar in magnitude (see figure A-1 and compare Models a and b). This finding holds up only when data from the more recent period, 1989 to 1994, are employed. Basically, the time-trend approach reports a smoothed version of the yearly indicator approach.

The rise in the technological change indexes during the early 1980s could suggest technological regress, defined as an upward shift in the cost function due to technological change. The technological change estimates from the early period (essentially, the start-up phase for ACH payments) are difficult to interpret, however, because it is plausible that the ACH cost function may have shifted substantially across time not only because of technological change, but also because of learning-by-doing economies.[32]

■ 32 Learning-by-doing economies may have resulted from several factors. Workers performing repetitive tasks may have learned from cumulative experience to perform these jobs more quickly and efficiently. Operations management at a processing site may have been able to call on its experience to modify job assignments, rearrange the layout of facilities, or devise ways to reduce paper or other material wastes. In addition, software engineering may have improved computers' efficiency in processing batches of payments, so that the same amount of computer technology could process more ACH payments faster, or with greater security enhancement, and at lower cost.

TABLE A-2

Estimated Cost Elasticities (at sample means)

Sample Period	Cost-Function Model: OLS Model 1, Model a	OLS Model 1, Model b	OLS Model 2, Model a	OLS Model 2, Model b	ITSUR Model 1	ITSUR Model 2
1979–1994	0.885[a]	0.881[a]	0.638[a]	0.640[a]	—	—
1989	0.762[a]		0.424[a]		—	—
1990	0.852[a]		0.523[a]		—	—
1991	0.897		0.671[a]		—	—
1992	0.968		0.678[a]		—	—
1993	0.810[a]		0.648[a]		—	—
1994	0.828[a]		0.748		—	—
1989–1994	0.849[a]	0.851[a]	0.634[a]	0.648[a]	0.761[a]	0.448[a]

a. Cost elasticity estimate is statistically different from one.
SOURCE: Authors' calculations.

These cost-function shifts are difficult to model separately, particularly when a high correlation exists between output and a time trend. In addition, we use year-specific indicator variables or a time trend and its squared term to derive estimates of technological change. Thus, it need not be the case that technological regress occurred: Other time-specific factors could also have increased ACH processing costs in the early years. Plausible candidates include the one-time transition costs to newer technologies, shifts to higher-quality (higher-cost) services with more bells and whistles, and various changes in cost-accounting procedures. Unfortunately, adequate control variables for such factors are unavailable, so we could not further decompose these time-specific effects.

Estimates of technological change derived using models with more control variables tend to be larger, possibly because the models incorporate a greater number of environmental variables that control for site-specific characteristics.

Scale Economies

Estimates of cost elasticities at the sample means for the OLS models are reported in table A-2 for several different periods. Inclusion of additional site-specific regressors affects the estimates of scale economies, with OLS Model 2 yielding larger estimates (smaller cost elasticities) than OLS Model 1. All of these cost elasticities are statistically different from one at the 95 percent confidence level, confirming the presence of scale economies. Essentially, OLS Model 1 assigns more of the cost savings to technological change (and consequently, less to scale economies) than does OLS Model 2. Our estimates of cost elasticities are fairly close to the 0.70 to 0.75 figures reported in Humphrey (1982, 1984, 1985). Given the high degree of multicollinearity present in the data (particularly between output and a time trend), which overstates standard errors and implies a bias toward rejecting the hypothesis of scale economies, a finding of statistically significant scale economies shows strong support for this hypothesis.

As a further test of robustness, we also estimate the two OLS models using quarterly cross-sectional data for each year. Again, the scale economy estimates are larger when site-specific characteristics are included. Generally, the yearly cost elasticity estimates are statistically different from one at the 95 percent confidence level. Using OLS Model 1 in 1991 and 1992, however, we do not find statistically significant scale economies. These estimates are bound to be less precise than those generated by our other models because they are based on very few observations.

In summary, we subjected our cost-function model to a number of tests for robustness, primarily by varying the sample period and the regressors. While the magnitude of some of the results varies significantly, our qualitative findings across models are consistent. The sharp declines in unit cost appear to stem primarily from technological change and scale economies. Our finding of significant scale economies is robust to the model specification and selection of sample period.

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