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# The Increasing Importance of Proximity for Exports from U.S. States

Cletus C. Coughlin

Income, trade policies, transportation costs, technology, and many other variables combine to determine the levels of international trade flows. Not only do changes in these determinants affect the levels of trade flows, they can also have important consequences for the geographic pattern of a country's trade. Some changes are generally thought to increase the proportion of a country's trade with nearby countries relative to its other trading partners, while other changes tend to decrease this proportion. For example, if a country enters into a trade agreement with nearby countries, it is likely that the country's share of trade with nearby countries will increase relative to its trade with other trading partners. On the other hand, declining transportation costs can reduce the cost disadvantage of trading with distant countries and could thereby increase trade with more distant countries relative to those nearby.

This paper focuses on the changing geography of merchandise exports from individual U.S. states to foreign countries. Due to data limitations, exports of services are not examined. Two basic questions are addressed. First, how has the geographic distribution of exports from individual U.S. states changed? Second, which changes in the economic environment appear to account for the observed changes in the geographic distribution of state exports?

A useful measure for analyzing the changing geography of trade is the *distance of trade*, which is simply the average distance that a country's (state's) international trade is transported.[1] If a country's (state's) distance of trade is declining (increasing) over time, then its trade is becoming more (less) intense with nearer countries relative to countries farther away. In other words, a declining (increasing) distance of trade means that the shares of a country's (state's) trade with nearby trading partners is rising (falling) relative to trade with its more distant trading partners.

The analysis begins by summarizing the facts and the explanations concerning the geographic distribution of exports throughout the world. An important feature of the economic geography of trade flows is the distance that separates a state from its trading partners. Distance is generally thought to play a key role in the geographic distribution of trade for two reasons. First, transportation costs are higher for longer distances. Second, the costs of accessing information about foreign markets and establishing a trade relationship in those markets are higher for longer distances.[2] Thus, a country's trade with more distant countries is deterred.

Despite the "death of distance" associated with the communications revolution, proximity appears to be increasingly important for trade flows.[3] Using the bilateral trade flows of 150 countries, Carrere and Schiff (2004) find that during 1962-2000 the distance of (non-fuel merchandise) trade declines for the average country and that countries with a declining distance of trade were twice as numerous as those with an increasing distance of trade.

After reviewing the geography of exports from the perspective of individual countries throughout the world, I examine the geography of the exports

[1] The calculation is straightforward. Assume a state's exports are shipped to two countries and that the value of exports sent to one country, which is 1,000 miles away, is \$800 and the value sent to the other country, which is 3,000 miles away, is \$1,200. Thus, 40 percent of the state's exports are transported 1,000 miles and 60 percent are transported 3,000 miles. The distance of trade is 2,200 miles ($40\% \times 1{,}000 + 60\% \times 3{,}000$).

[2] See Rauch (1999) for additional discussion of this point.

[3] The death of distance has become a popular term because of *The Death of Distance: How the Communications Revolution Will Change Our Lives* by Frances Cairncross (1997). The book focuses on the economic and social importance of how advances in technology have virtually eliminated distance as a cost in communicating ideas and data. Possibly, this death of distance has made foreign direct investment and trade with proximate countries a more efficient way to serve markets than trade over long distances.

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from individual U.S. states to their trading-partner countries. The distance of trade is calculated annually for each state beginning in 1988, the first year of detailed geographic data for individual states. Similar to the finding for the majority of countries, the majority of, but not all, states show a declining distance of trade.

The findings for individual states allow for an examination of some explanations that may account for the changing geographic distribution of exports at the state level. The uneven income growth of trading partners, the implementation of the North American Free Trade Agreement (NAFTA), and changing transportation costs are the "usual suspects." Possibly, incomes of nearby trading partners have increased more rapidly than incomes of more distant trading partners. Such a development might stimulate trade with nearby trading partners (relative to those more distant) so that a state's distance of trade declines. Similarly, the implementation of NAFTA, by reducing trade barriers between the United States and its major North American trading partners, might tend to decrease a state's distance of trade. Finally, it is possible that transportation costs have changed to increase the attractiveness of trading with nearby countries. My goal is to provide suggestive evidence on how these three factors have changed the geography of the exports of states, which in turn provides insights concerning the changing geography of total U.S. exports.

## THE CHANGING GEOGRAPHY OF WORLD TRADE

During the second half of the twentieth century, the volume of international trade throughout the world increased more rapidly than output. Baier and Bergstrand (2001) attempted to identify the reasons for the growth of international trade between the late 1950s and the late 1980s. They estimated that declines in transportation costs explained about 8 percent of the average trade growth of several developed countries, tariff-rate reductions about 25 percent, and income growth the remaining 67 percent. The question for the current study is straightforward. Have these determinants, which are related to one another, changed in such a way that would alter systematically the geography of state export flows? To date, systematic evidence relating these determinants to state export flows is lacking. In fact, little evidence exists as to how changes in these determinants of trade have affected the geography of world trade flows.

### *Changing Transportation Costs—Usual Suspect No. 1*

The costs of transporting goods from a producer in one country to a final user in another country are large. Putting a precise number on "large" is very difficult and undoubtedly varies across goods and countries. Despite this difficulty, Anderson and van Wincoop (forthcoming) estimate international transportation costs for industrialized countries to be equivalent to a tax of 21 percent. Additional transportation costs are incurred to move internationally traded goods within exporting countries and within importing countries. Not surprisingly, changes in transportation costs can have large effects on trade flows. Not only can reductions in transportation costs lead to increased trade flows directly, but also indirectly by affecting the profitability of production in specific locations.

A point that might not be intuitively obvious is that a decline in transportation costs might cause either an increase or a decrease in a country's (state's) distance of trade. In the context of ocean shipping costs, it depends on the nature of the change in transportation costs.

Ocean shipping transportation costs can be divided into those unrelated to distance, known as dwell costs, and those related to distance, known as distance costs. Dwell costs cover various aspects, such as the cost of loading and unloading ships and the cost (including time) of queuing outside a port waiting to be serviced. On the other hand, distance costs are related positively to the distance from port to port. For example, the longer the distance between ports, the larger the fuel costs of transporting a given shipment.

In theory, reductions in both dwell costs and distance costs increase international trade flows; however, their effects on the distance of trade differ. A reduction in dwell costs increases the incentive to trade with nearby locations relative to distant locations; this is so because dwell costs make up a larger proportion of total transport costs for shorter distances.[4] Thus, a reduction in dwell costs tends to

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[4] For example, assume dwell costs of $100,000 and distance costs per mile of $200. If so, then the cost of a trip of 1,000 miles is $300,000 and a trip of 4,500 miles is $1 million. Thus, for the shorter (longer) trip the respective shares of the transportation costs are 33 (10) percent for the dwell costs and 67 (90) percent for the distance costs. As a result, a reduction in dwell costs, say from $100,000 to $50,000, has a larger proportional effect on costs for the shorter trip; a reduction in distance costs, say from $200 per mile to $100 per mile, has a larger proportional effect on costs for the longer trip.

reduce the distance of trade. On the other hand, a reduction in distance costs increases the incentive to trade with distant locations relative to nearby locations. The reduced cost per mile causes a larger proportional decrease in transport costs for longer distances. Thus, a reduction in distance costs tends to increase the distance of trade.[5]

Because evidence on dwell and distance costs is limited, it is very difficult to reach firm conclusions concerning their evolution and, in turn, their effects on the distance of trade. Hummels (1999) provides some evidence suggesting technological changes associated with containerization have reduced both dwell and distance costs.[6] Containerization is a system of inter-modal transport that uses standard-sized containers that can be loaded directly onto container ships, freight trains, and trucks. Dwell costs are reduced because ships spend less time in port and the cargo can be handled more efficiently. Meanwhile, the larger and faster ships allowed by containerization have reduced shipping costs on a ton-mile basis while the ship is moving between ports. It is likely, however, that containerization lowered dwell costs relatively more than distance costs. In addition, containerization, by eliminating the unpacking and packing of cargoes at every change in transport mode, likely reduced the cost of the inland movement of goods by making the inter-modal transfer of goods easier. Such changes should tend to reduce the distance of trade.

Containerization, however, is only one of the many changes that have affected transportation costs. Regulatory policies and energy prices are two additional factors. Whether transportation costs have in fact declined in recent decades is uncertain because of the lack of evidence on this issue. For example, Carrere and Schiff (2004) conclude that transportation costs have not necessarily declined across all modes of transportation. First, they cite evidence provided by Hummels (1999), who found that ocean freight rates have increased, while air freight rates have declined rapidly. Hummels also found evidence that overland transport costs in the United States have declined relative to ocean freight rates. In fact, according to Glaeser and Kohlhase (2004), the costs of moving goods by rail and by truck within the United States have fallen substantially in a nearly continuous manner since 1890.[7]

While far from precise in terms of quantifying the changes in transportation costs, these findings are consistent with recent changes in the relative shares of the methods used to transport U.S. exports. Over time, air and land shipments have displaced ocean shipments. Figure 1 shows that between 1980 and 2002 the shares of air and land shipments increased by 11.9 and 14.5 percentage points, respectively, while the share of ocean shipments declined by 26.4 percentage points. As a result, the majority of U.S. exports are no longer shipped on ocean vessels. In fact, in 2002, shipments by air and land accounted for larger shares of exports than shipments by sea.

A second source of evidence relevant to changes in transportation costs relies on studies that estimate the relationship between distance and international trade flows.[8] Numerous studies have generated estimates of the distance sensitivity of trade or, using more precise terminology, the distance elasticity of trade: that is, the percentage change in trade flows associated with a given percentage increase in the distance separating one country from its trading partners. These studies find, not surprisingly, that the larger the distance that separates two countries, the smaller the value of trade moving between them. More important for the current discussion is the common finding that distance is playing a changing role over time in the geographic distribution of trade. For example, results by Frankel (1997) indicate that

5 A decline in transportation costs might not affect the distance of trade. Eichengreen and Irwin (1998) note that the cost of transporting goods over various distances could decline proportionately. In this case, which they call "distance-neutral" technological progress, such a decline in transportation costs would tend to leave the distance of trade unchanged.

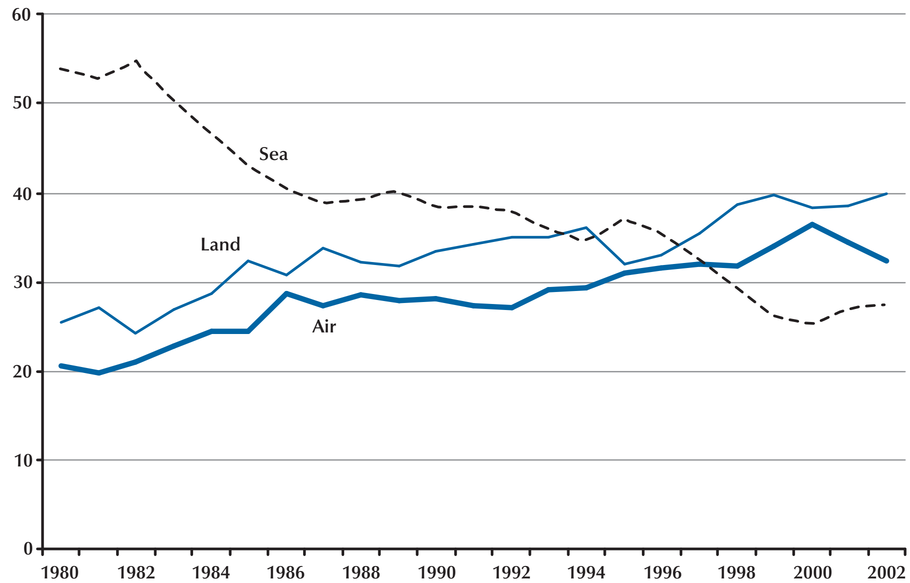
6 Hummels (1999) identified as important the following institutional changes that have affected ocean shipping: open registry shipping, which allows ships to be registered under flags of convenience to avoid some regulatory and manning costs imposed by some countries, and cargo reservation policies, which were to designed to ensure that a country's own ships were granted a substantial share of that country's liner traffic.

7 Glaeser and Kohlhase (2004) find that the cost of moving goods has declined by roughly 90 percent since 1890. The costs of transporting goods by rail and by truck have declined at annual rates of 2.5 percent and 2.0 percent, respectively. As a result, they conclude that the cost of moving goods within the United States is no longer an important component of the production process.

8 Using distance as a proxy for transportation costs is problematic for numerous reasons. Distance is generally measured with the "great circle" formula. Actual transportation routes are not this direct. In addition, the use of distance assumes one route between trading regions. Trade between two geographically large countries, such as the United States and Canada, is conducted over many routes. Multiple routes and multiple modes of transportation increase the doubts that distance is a good proxy for transportation costs. As discussed in the text, many transportation costs, such as dwell costs, clearly do not vary with distance. Finally, actual freight rates often bear little connection to distance traveled.

## Figure 1

**U.S. Exports by Transport Mode, 1980-2002**




NOTE: The variable Land was created by subtracting the sum of air and vessel exports from total exports.
SOURCE: U.S. Bureau of the Census.

if the distance separating a country from two of its trading partners differed by 10 percent, then trade flows between the country and its more distant trading partner (relative to the country and its nearby partner) were 4 percent less during the 1960s and 7 percent less during the 1990s. Overall, the majority of studies indicate that the distance sensitivity of trade is not shrinking, but rather increasing.[9] Such a change would tend to decrease the distance of trade.

A third piece of evidence concerning transportation costs highlights the impact of time.[10] The cost consequences of delays can be quite large. Hummels (2001) has estimated that each day saved in shipping time was worth 0.8 percent of the value of manufactured goods. Overall, faster transport between 1958 and 1998 due to increased air shipping and speedier ocean vessels was equivalent to reducing tariffs on manufactured goods from 32 percent to 9 percent.[11]

Time costs have likely played a key role in the change in shipping modes. Because shipping by air is much faster than shipping by sea, the decline in air shipping prices relative to ocean shipping prices has made the saving of time less expensive. This has

[9] Disdier and Head (2004), in a thorough examination of numerous studies using gravity models, conclude that the impact of distance is increasing, albeit slightly, over time. Brun et al. (2003) and Coe et al. (2002) reach a similar conclusion. Berthelon and Freund (2004) find that, rather than a shift in the composition of trade, an increase in the distance sensitivity for more than 25 percent of the industries examined accounts for this result. Research by Rauch (1999), contrary to most studies, finds that the effect of increased distance on trade has declined since 1970.

[10] Hummels (2001) identified numerous costs associated with shipping time and its variability. Lengthy and variable shipping times cause firms to incur inventory and depreciation costs. Inventory-holding costs include the financing costs of goods in transit and the costs of maintaining larger inventories at final destinations to handle variation in arrival times. Examples of depreciation, which reflect any reason to prefer a newer good to an older good, include the spoilage of goods (fresh produce), goods with timely information content (newspapers), and goods with characteristics whose demand is difficult to forecast (fashion apparel).

[11] In general, transportation costs, including time costs, have risen as a result of the terrorist attacks of September 11, 2001. Insurance rates, especially for shipping in the Middle East, have increased sharply. Additional scrutiny of containers has also increased costs. According to the Organisation for Economic Co-operation and Development (2002), these costs could run from 1 to 3 percent of trade. Moreover, additional security measures cause delays for importers and exporters that further increase transportation costs.

led to relatively large increases in air shipping and contributed to an increasing frequency of the various stages of the production of final goods occurring in different countries. The timeliness of air shipping can play a key role in the international trade of intermediate goods that characterizes international production fragmentation.

Some doubts arise about whether transportation costs have truly declined when distances of trade are examined. Carrere and Schiff (2004) examined the distance of trade for approximately 150 countries between 1962 and 2000.[12] They found that the distance of trade declined for the average country worldwide. For every country with an "empirically significant" increasing distance of trade, there are nearly two countries with a decreasing distance of trade.[13] For the average country's exports during 2000, the distance of trade was slightly less than 4,000 miles. The average decline in the distance of trade between 1962 and 2000 was approximately 5 percent. For the United States the distance of trade based on exports was roughly 4,160 miles; however, contrary to the average country, the distance of trade for U.S. exports *increased*. Over the entire period, the distance of trade for U.S. exports increased by slightly less than 8 percent. The U.S. distance of trade did not increase in a consistent pattern throughout the 39-year period. In fact, during the 1980s and 1990s, the U.S. distance of trade declined.

A declining distance of trade, however, does not preclude declining transportation costs. As discussed previously, a decline in transportation costs can cause either an increase or a decrease in the distance of trade. If the decline is due to a reduction in dwell costs, then the distance of trade will tend to decline. It is possible that the distance of trade is trending downward because of changes in other determinants. I now turn to one possibility, a proliferation of regional trade agreements.

## Regional Trade Agreements—Usual Suspect No. 2

A regional trade agreement eliminates barriers for trade flows between members, while maintaining the barriers for trade flows between members and nonmembers. Standard customs union theory predicts that these agreements will lead to increased trade between member countries (termed trade creation) and decreased trade between members and nonmembers (termed trade diversion). Because such agreements tend to be formed between neighboring countries, it is reasonable to expect that regional trade agreements will decrease a member's distance of trade. The stronger the effects of both trade creation and trade diversion, the larger is the decline in the distance of trade for a member.

Carrere and Schiff (2004) examine the impact of NAFTA and seven other regional integration agreements on the evolution of the members' distance of trade. Almost without exception, they find that regional trade agreements tend to reduce the distance of trade for exports. In other words, regional trade agreements, such as NAFTA, change the geographic trade pattern toward larger shares of trade with nearby relative to more distant trading partners.

## Uneven Income Growth—Usual Suspect No. 3

A country's distance of trade can be affected by the pattern of income growth of its trading partners. Other things the same, if a country's nearby trading partners have greater income growth relative to its more distant trading partners, the country's distance of trade will decline because trade with its nearby partners will increase relative to trading with more distant partners.

Carrere and Schiff (2004) provide some examples, as well as regression results, to suggest this explanation may be important. They note that countries in the East Asia–Pacific region tended to grow faster than the world average during 1962-79, 1980-89, and 1990-2000. For each period, the trend distance of trade is negative for this region. A similar example involves the countries in NAFTA. The distance of trade tended to increase during 1962-89 and decrease during 1990-2000. Consistent with this explanation, growth in the NAFTA countries was below the world average during 1962-1989 and above the world average during 1990-2000.

[12] The calculation of the distance of trade (*DOT*) from country $i$ during time period $t$ is straightforward. $DOT_i = \Sigma\, d_{ij}\, s_{ij}$, where $d$ is the (spherical) distance from the leading (economic) city in country $i$ to the leading city in destination country $j$ and $s$ is the share of $i$'s exports to country $j$. The summation occurs over all destination countries. A simple numerical example is contained in footnote 1.

[13] The authors define empirically significant as an absolute change in the estimated distance of trade of more than 5.5 percent. For the sample of 150 countries, 77 countries had an empirically significant negative change in either the distance of exports or imports, while 39 countries had an empirically significant positive change.

**Table 1**

**Export Destination Share by Region (%)**

| | 1988-92 | 1993-97 | 1998-2002 |
|---|---|---|---|
| Canada | 20.4 | 22.4 | 23.4 |
| Mexico | 7.9 | 9.6 | 13.7 |
| Latin America and the Caribbean | 6.4 | 7.8 | 7.4 |
| Europe | 27.8 | 22.8 | 23.2 |
| Asia | 33.2 | 33.9 | 29.1 |
| Africa | 1.7 | 1.4 | 1.2 |
| Oceania | 2.5 | 2.2 | 2.0 |

### *International Production Fragmentation—A New Suspect*

In addition to the usual suspects, one new suspect has emerged: international production fragmentation. This development has led to major changes in the location of production and trade flows. A lack of data precludes an empirical examination of this explanation for state-level exports. Nonetheless, for completeness, a brief discussion of the relationship between international production fragmentation and the distance of trade seems warranted.

One feature of the expanding integration of world markets is that companies are outsourcing increasing amounts of the production process. This internationalization of production allows firms to achieve productivity gains by taking advantage of proximity to markets and/or low-cost labor. The net effect on the distance of trade is unclear. Despite locating production close to markets, the likely reduction in the distance of trade is uncertain because it is unclear how the increased use of low-cost labor will affect the distance of trade. One can easily find examples for the United States, such as the growth of maquiladoras in Mexico, which are associated with a declining distance of trade. On the other hand, the increased use by U.S. firms of low-cost labor in China tends to increase the distance of trade.

Another factor contributing to a declining distance of trade for the United States is the increasing use of "just-in-time" inventory management. New information and communications technology have propelled this management. For industries, such as apparel, in which timely delivery has become increasingly important, the distance of trade has decreased. Evans and Harrigan (2003) show that U.S. apparel imports have shifted from Asian countries to Mexico and Caribbean countries.[14]

The increasing importance of international production fragmentation is consistent with findings by Berthelon and Freund (2004) on the increasing distance sensitivity of trade. They find an increasing distance sensitivity of trade for 25 percent of the industries they examined. Accordingly, trade with nearby countries has become more attractive relative to trade with more distant countries. This increasing distance sensitivity might be the result of technological change that enhances the advantages of proximity. One consequence of this change is an increased share of trade between the countries within a region, such as between the countries in North and South America, relative to trade across regions, such as between countries in North America and East Asia.

## GEOGRAPHY OF U.S. STATE EXPORTS

The distance of trade for the United States can be analyzed by taking a close look at the geography of exports using state data. In view of the declining U.S. distance of trade during the past two decades, it is reasonable to expect that the change in the distance of trade (using state export data summed over all states) will indicate relatively more intense trade with proximate regions than with distant regions.

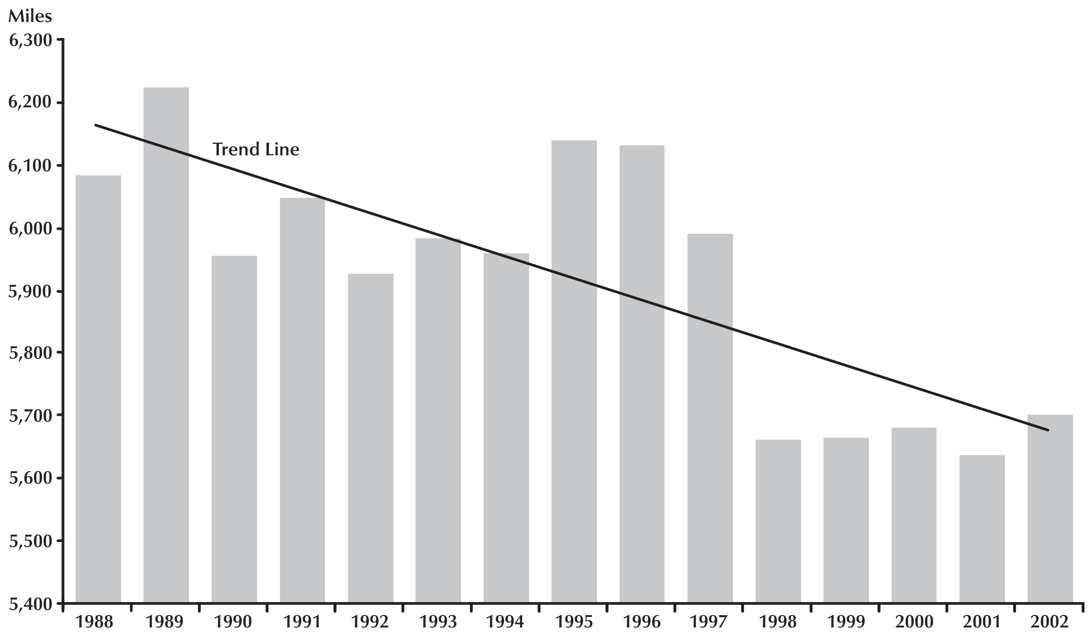
The data in Table 1 show how the destination of U.S. exports has changed for three five-year periods during 1988-2002.[15] The destinations for U.S. exports are split into Canada and Mexico, the two major North American trading partners of the United States as a whole, and then the rest of the world is split roughly into continents. Comparing 1988-92 with 1998-2002, it is clear that Canada, Mexico, and Latin America and the Caribbean are the destinations for increasing shares of U.S. exports, while Europe, Asia, Africa, and Oceania are the destinations for decreasing shares of U.S. exports. The shift in the share between the regions with an

[14] Abernathy et al. (1999) argue that three retail apparel/textile regions are developing in the world—the United States plus Mexico and the Caribbean Basin, Japan plus East and Southeast Asia, and Western Europe plus Eastern Europe and North Africa.

[15] Export shares are calculated by dividing U.S. exports to each region (averaged across five-year periods) by total U.S. exports to all seven regions (averaged across five-year periods). Regions are constructed using the top 50 export markets for each state, which account for more than 90 percent of each state's total exports. The definition of regions used for Tables 1 and 6 is not identical to the one used by Coughlin and Wall (2003).

**Figure 2**

**National Distance of Trade, Calculated Using State-to-Country Distances, 1988-2002**




increasing share and those with a decreasing share was 9.8 percentage points. Most noteworthy were the increases by Mexico and Canada of 5.8 and 2.9 percentage points, respectively, and the decreases in export shares for Europe and Asia of 4.6 and 4.1 percentage points, respectively.

The changing export shares of proximate and distant regions are suggestive of the changing distance of trade for the nation as a whole. Figure 2 shows the yearly national distance of trade from 1988-2002.[16] The distance of trade is substantially lower for the years at the end of the period compared with the earlier years. The range of national distance of trade was 5,664 to 5,702 miles for 1998 through 2002, while no year prior to 1998 had a distance of trade less than 5,930 miles.[17]

Because showing the distance of trade for each state (51) for each year (15) would yield a very large number of observations (765), I have chosen to summarize the data.[18] Figure 3 shows the distribution of distance of trade across all states at the beginning of the sample period in the upper histogram and at the end of the sample period in the lower histogram.[19] Measured on the horizontal axis is the distance of trade for the following ranges in miles: 1,000 to 3,000; 3,000 to 5,000; 5,000 to 7,000; 7,000 to 9,000; 9,000 to 11,000; 11,000 to 13,000; and 13,000 to 15,000. The vertical axis shows the percentage of states with a distance of trade falling into the given ranges. For 1988, two-thirds of the states had a distance of trade within the 5,000 to 7,000 mile range. Two states, Hawaii and Alaska, were outliers with distances of trade in the 13,000 to 15,000 mile range.

Comparing 2002 with 1988, one can easily see the declining distance of trade in the figure. Two-thirds of the states fell into the 5,000 to 7,000 mile range in 1988, whereas 45.1 percent fell into that range in 2002. Generally speaking, the decrease in the 5,000 to 7,000 mile range was matched by an

[16] This measure was calculated using the top 50 export markets for each state.

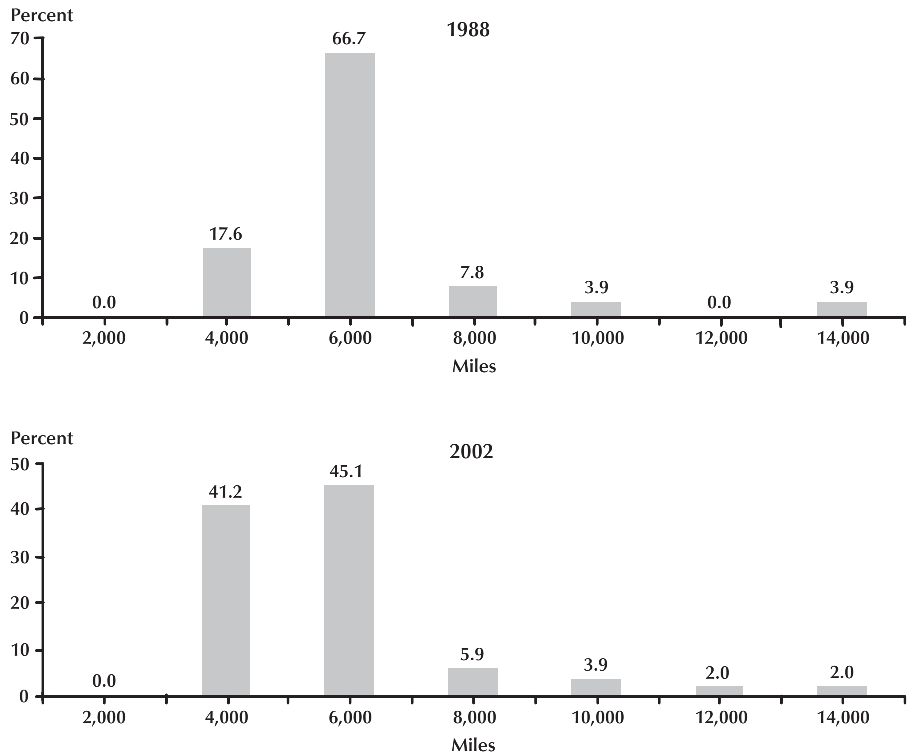
[17] The fact that the U.S. distance of trade measure calculated by Carrere and Schiff (2004) is substantially less than my measure reflects various factors, but most notably how our different measures deal with the impact of trade with Canada and Mexico. Carrere and Schiff use the distance between national capital cities (e.g., Washington, D.C., to Ottawa and Mexico City), while I use the distance between the major economic city in a state to the major economic city in Canada (Toronto) and in Mexico (Mexico City). For 2002 this methodological difference contributes 369 miles to the gap between the two measures.

[18] For convenience, Washington, D.C., is referred to as a state.

[19] A state's distance of trade was calculated using its top 50 export markets.

**Figure 3**

**Probability Distribution of State Distance of Trade in 1988 and 2002**




increase in the 3,000 to 5,000 mile range. For 1988 the percentage of states in the 3,000 to 5,000 mile range was 17.6 percent, while for 2002 the percentage of states in this range was 41.2 percent.

Additional suggestive information about changes in the state-level export distance of trade, especially how the changes vary across states, was generated by estimating a simple regression equation. Similar to Carrere and Schiff (2004), the natural logarithm of a state's distance of trade (*lnDOT*) was regressed against time (*t*). For each state, a separate regression was estimated relating the state's distance of trade to time using annual data from 1988-2002. The specific equation was as follows:

$$lnDOT = \alpha + \beta t + \varepsilon, \qquad (1)$$

where $\alpha$ is the intercept term, $\beta$ is the coefficient relating time to the distance of trade, and $\varepsilon$ is the error term.

Table 2 shows the estimated $\beta$ for each state, ordered from the smallest (i.e., most negative) value to the largest. The estimate for Montana, –0.0429, was the smallest, while the estimate for Vermont, 0.0388, was the largest. Regressions for 40 of the 51 states generated negative estimates for $\beta$, while regressions for 11 of the 51 states generated positive estimates.[20] Table 2 also shows the percentage change in the distance of trade based on the coefficient estimate.[21] The smaller (i.e., more negative) the coefficient, the larger is the estimated percentage decline in a state's distance of trade. Twenty-seven states showed declines in their distance of trade that exceeded 10 percent, while five states showed increases of more than 10 percent.

## POSSIBLE DETERMINANTS OF THE CHANGING GEOGRAPHY OF STATE EXPORTS

In light of the changing geography of state exports—toward relatively larger shares of trade

[20] Using the 5 percent level, only 1 of the 51 estimates is not statistically significant.

[21] The calculation of the estimated percentage change in the distance of trade follows from the fact that the coefficient estimate of $\beta$ is an instantaneous rate of growth. The formula is $(e^{\beta \times 14} - 1)100$.

## Table 2

### Time-Trend Analysis of the Distance of Trade, 1988-2002

| State | State rank | Coefficient estimate, $\beta$ | $t$ Statistic | Estimated percentage change in distance of trade |
|---|---|---|---|---|
| Montana | 1 | –0.0429 | –42.2 | –45.2 |
| Indiana | 2 | –0.0253 | –86.5 | –29.8 |
| South Carolina | 3 | –0.0248 | –65.6 | –29.3 |
| Mississippi | 4 | –0.0235 | –49.3 | –28.1 |
| Wyoming | 5 | –0.0230 | –48.2 | –27.6 |
| Texas | 6 | –0.0224 | –47.4 | –27.0 |
| Alabama | 7 | –0.0213 | –53.7 | –25.7 |
| North Carolina | 8 | –0.0191 | –86.5 | –23.4 |
| Tennessee | 9 | –0.0171 | –54.6 | –21.3 |
| Ohio | 10 | –0.0170 | –41.0 | –21.1 |
| South Dakota | 11 | –0.0141 | –18.9 | –17.9 |
| Illinois | 12 | –0.0113 | –26.5 | –14.7 |
| Utah | 13 | –0.0110 | –18.1 | –14.2 |
| Iowa | 14 | –0.0108 | –31.9 | –14.1 |
| Oklahoma | 15 | –0.0107 | –21.4 | –14.0 |
| Kentucky | 16 | –0.0106 | –23.6 | –13.8 |
| Pennsylvania | 17 | –0.0102 | –86.1 | –13.3 |
| Nevada | 18 | –0.0102 | –11.8 | –13.3 |
| New York | 19 | –0.0098 | –34.3 | –12.8 |
| Louisiana | 20 | –0.0097 | –42.2 | –12.7 |
| Alaska | 21 | –0.0093 | –48.5 | –12.2 |
| Arizona | 22 | –0.0090 | –15.2 | –11.8 |
| Georgia | 23 | –0.0086 | –27.1 | –11.3 |
| Kansas | 24 | –0.0082 | –28.4 | –10.8 |
| Florida | 25 | –0.0081 | –20.0 | –10.7 |
| California | 26 | –0.0081 | –29.3 | –10.7 |
| Wisconsin | 27 | –0.0079 | –27.2 | –10.4 |
| Missouri | 28 | –0.0072 | –16.0 | –9.5 |
| Nebraska | 29 | –0.0070 | –14.1 | –9.3 |
| New Hampshire | 30 | –0.0060 | –18.2 | –8.1 |
| Connecticut | 31 | –0.0054 | –18.9 | –7.3 |
| Arkansas | 32 | –0.0048 | –14.4 | –6.5 |
| Washington | 33 | –0.0039 | –11.3 | –5.4 |
| Idaho | 34 | –0.0034 | –13.1 | –4.6 |
| Oregon | 35 | –0.0033 | –15.1 | –4.5 |
| Minnesota | 36 | –0.0025 | –12.9 | –3.4 |
| Virginia | 37 | –0.0025 | –13.6 | –3.4 |
| Colorado | 38 | –0.0021 | –6.3 | –2.9 |
| Rhode Island | 39 | –0.0007 | –2.9 | –0.9 |
| New Jersey | 40 | –0.0005 | –2.4 | –0.7 |
| Massachusetts | 41 | 0.0003 | 1.0 | 0.4 |
| Maine | 42 | 0.0024 | 4.8 | 3.4 |
| West Virginia | 43 | 0.0031 | 9.2 | 4.4 |
| Michigan | 44 | 0.0044 | 18.9 | 6.4 |
| Hawaii | 45 | 0.0051 | 10.2 | 7.4 |
| Maryland | 46 | 0.0058 | 13.0 | 8.4 |
| District of Columbia | 47 | 0.0155 | 18.7 | 24.2 |
| North Dakota | 48 | 0.0163 | 35.2 | 25.6 |
| Delaware | 49 | 0.0209 | 42.9 | 34.0 |
| New Mexico | 50 | 0.0277 | 25.6 | 47.4 |
| Vermont | 51 | 0.0388 | 56.6 | 72.1 |

with proximate countries—I examine the same explanations that apply to the changing world geography of trade. As will become apparent, any strong conclusions are precluded by analysis of the existing data.

## Changing Transportation Costs

To generate some basic facts about state exports and distance, the following regression was estimated for each state using its top 30 export markets for each year from 1988 through 2002:

$$EXPSHARE = \alpha + \beta RGDP + \gamma DIST + \varepsilon, \quad (2)$$

where *EXPSHARE* is the share of a state's exports shipped to a specific country; *RGDP* is the real gross domestic product (GDP) of the destination country; *DIST* is the distance from the state to the destination country; $\alpha$, $\beta$, and $\gamma$ are the parameters to be estimated; and $\varepsilon$ is the error term.[22] Because higher real GDP should be associated with larger export shares, the expected sign for the estimate of $\beta$ is positive. Because longer distances between the exporting state and the destination country should proxy for higher transportation costs, the expected sign for the estimate of $\gamma$ is negative.

The results indicate that the higher the real GDP of a country, the higher is its export share.[23] Not surprisingly, for the vast majority of states (45), the larger the distance that separates a state from an export destination, the smaller the export share of the destination country. Summary results for the estimate of $\gamma$ are listed in Table 3.[24] An important question is how the estimated relationship between distance and export share is changing over time. In Table 3 the "Trend" column provides this information. Similar to the results cited earlier for the relationship between distance and trade flows using country data, the relationship between distance and trade shares using state data indicates that the effect of distance is increasing the trade shares of proximate countries at the expense of trade with distant countries. This holds for 42 of the 51 states—for 38 states the sign of the parameter estimate for distance is negative, with a declining trend (i.e., becoming more negative), and for 4 states the sign of the parameter estimate for distance is positive, with a declining trend (i.e., becoming less positive).[25]

Thus, for most states the results suggest that the parameter estimate for distance is declining over time. Such a change should tend to decrease a given state's distance of trade over time because the export shares of more distant countries are declining more rapidly in latter periods. One possible explanation for these results is that changes in transportation costs now favor land transportation.

As mentioned previously, Glaeser and Kohlhase (2004) found that the costs of moving goods by rail and by truck within the United States have fallen substantially in a nearly continuous manner since 1890. Whether such declines also apply to trade with Canada and Mexico is unclear, but there are some reasons to think that these international transport costs have declined. Exports from the United States to Canada and Mexico are generally over land. From 1988 through 2002, roughly 90 percent of U.S. exports to Canada and Mexico were transported over land. Declining costs of transportation over land have tended to favor state exports to Canada and Mexico relative to trade with more distant locations. The importance of such a change, however, is difficult to separate from the effects of NAFTA.

## NAFTA

NAFTA has the potential to affect a variety of trade barriers. Extending the previous discussion, a question is whether NAFTA has had any impact on transportation costs associated with crossing the border between the United States and Mexico. The answer appears to be no.

Seamless border crossings were envisioned as a feature of NAFTA; however, Haralambides and Londoño-Kent (2004) note that reality differs substantially from this vision. To complete the physical

[22] The top 30 export markets can vary over time for a given state and vary across states. The countries used in the regressions for each state are available upon request from the author.

[23] These results are not reported; however, they are available upon request from the author.

[24] Strong statements concerning this evidence are not justified: Statistical significance at the 10 percent level was found for the relationship between distance and export share for 20 percent of the estimates.

[25] Additional statistical analysis has been undertaken, the foundations of which can be found in Cheng and Wall (forthcoming), and has yielded similar results concerning how the distance coefficient has changed over time. For each of the five leading U.S. exports markets—Canada, Mexico, Japan, Germany, and the United Kingdom—the following two-step procedure was used. First, using annual observations covering five years (1988-92, 1993-97, and 1998-2002) and all states, the share of a state's exports sent to a specific country was regressed on a time dummy and a state-country dummy. Second, the state-country fixed-effect estimate was regressed on the distance from the state to the specific country. These results are available upon request from the author.

**Table 3**

**The Distance Coefficient, $\gamma$**

| State | Sign | Trend | State | Sign | Trend |
|---|---|---|---|---|---|
| Alabama | – | Down | Montana | – | Down |
| Alaska | + | Down | Nebraska | – | Down |
| Arizona | – | Down | Nevada | – | Down |
| Arkansas | – | Down | New Hampshire | – | Down |
| California | – | Down | New Jersey | – | Down |
| Colorado | – | Down | New Mexico | + | Up |
| Connecticut | – | Down | New York | – | Down |
| Delaware | – | Up | North Carolina | – | Down |
| District of Columbia | – | Up | North Dakota | – | Up |
| Florida | – | Down | Ohio | – | Down |
| Georgia | – | Down | Oklahoma | – | Down |
| Hawaii | + | Up | Oregon | + | Down |
| Idaho | – | Down | Pennsylvania | – | Down |
| Illinois | – | Down | Rhode Island | – | Down |
| Indiana | – | Down | South Carolina | – | Down |
| Iowa | – | Down | South Dakota | – | Down |
| Kansas | – | Down | Tennessee | – | Down |
| Kentucky | – | Down | Texas | – | Down |
| Louisiana | + | Down | Utah | – | Down |
| Maine | – | Up | Vermont | – | Up |
| Maryland | – | Up | Virginia | – | Down |
| Massachusetts | – | Down | Washington | + | Down |
| Michigan | – | Up | West Virginia | – | Down |
| Minnesota | – | Down | Wisconsin | – | Down |
| Mississippi | – | Down | Wyoming | – | Down |
| Missouri | – | Down | | | |

transfer of goods from the United States to Mexico at the key United States–Mexico border crossing—that is, from Laredo, Texas, to Nuevo Laredo, Tamaulipas—requires a significant commitment of time, vehicles, and manpower. The cross-border transfer may take from two to four days, involve three or more trucks and trailers, and require three or four drivers. For comparison, the driving time from Chicago to Laredo is two days.

The original NAFTA agreement provided that, as of December 18, 1995, Mexican and U.S. trucking companies would have full access to and from each country's border states. Then, as of January 1, 2000, this reciprocal access was to have been extended throughout both countries. Given the inefficiencies affecting the movement of goods between the United States and Mexico, the implementation of NAFTA had the potential to substantially reduce cross-border transport costs.[26] However, for the period under consideration, the provisions governing cross-border trucking services were not in effect.

The Clinton administration, citing safety concerns, decided not to comply with the cross-border trucking services provisions. The lack of U.S. compliance produced gridlock in terms of implementing NAFTA's trucking services provisions. Following the

[26] Using estimates of the inefficiencies developed by Haralambides and Londoño-Kent (2004), Fox, Francois, and Londoño-Kent (2003) estimated that the elimination of the inefficiencies would cause U.S. exports to Mexico to increase by roughly $6 billion per year.

U.S. decision, a lengthy process involving much negotiation and a ruling by an arbitration panel to resolve the resulting disagreement ensued.[27] What appears to be the last roadblock to implementing the trucking services provisions was eliminated in June 2004 when the U.S. Supreme Court gave the Bush administration the authority to open U.S. roads to Mexican trucks without first completing an extensive environmental study. Thus, despite the potential for improvements, the actual effects of NAFTA on cross-border transport costs have been negligible to date and provide no reason for the declining distance of trade experienced by most states.

Despite having little impact on cross-border transport costs with respect to Mexico, NAFTA did reduce trade barriers for U.S. exporters. Let's examine regional trade agreements from the perspective of the state. Economic theory, known formally as customs union theory, suggests that NAFTA should cause any given region in the United States to trade more with Canada and Mexico and less with the rest of the world. Thus, NAFTA should be associated with a declining distance of trade for each state. However, recent theoretical advances as part of the new economic geography suggest that the trade creation/trade diversion dichotomy can be inadequate when factor mobility is taken into account. This mobility can shift resources across regions within a member country or across member-country borders. When resources are reallocated across regions, production locations and trade flows are altered as well.

Coughlin and Wall (2003) provide examples to illustrate the possible consequences of factor mobility. For example, consider a firm initially located in New Jersey. The formation of NAFTA, by adding Mexico to the United States–Canada free trade area, expands the spatial distributions of the firm's customers and suppliers southward. The firm that locates closer to Mexico will likely increase its potential for profits. If the firm relocates, goods that had been exported to NAFTA members from New Jersey would be exported from, perhaps, California. This relocation might also change the potential profitability of exporting to non-NAFTA markets by altering shipping costs. Shipments to Asia might become less expensive, while shipments to Europe might become more expensive. The key point is that the consequences of NAFTA for a given state's distance of trade are uncertain. Obviously, the effects on the distance of trade are likely to vary across states.

Coughlin and Wall (2003) use a gravity model to estimate how the effects of NAFTA differ across states.[28] The estimated percentage change in exports due to NAFTA is listed in Table 4.[29] The effect on a state's exports are disaggregated into five regions—Mexico, Canada, Europe, Asia, and Latin America. For example, Coughlin and Wall estimated that NAFTA caused Alabama's exports to Mexico, Canada, and Latin America to increase by 43.9 percent, 35.1 percent, and 14.7 percent, respectively. Meanwhile, NAFTA caused Alabama's exports to Europe and Asia to decline by 1.5 percent and 24.6 percent, respectively. The preceding changes caused Alabama's total exports, regardless of destination, to increase by 12.1 percent.

Overall, most states did experience increased exports to the other members of NAFTA. Exports to Mexico increased by more than 10 percent for 28 states. However, 13 states were estimated to have experienced declines in exports to Mexico as a result of NAFTA. Meanwhile, exports to Canada increased by more than 10 percent for 36 states. On the other hand, 11 states showed a decline in exports.

With respect to exports to nonmember countries, exports to Europe declined roughly 6 percent. Exports to Europe declined for 29 states; however, contrary to standard customs union theory, exports to Europe increased for 22 states. As with NAFTA's effects on exports to Europe, its effect on state exports to Asia was far from uniform. Exports to Asia declined for 20 states and increased for 31 states. Overall, NAFTA had a small negative effect on exports to Latin America. Exports declined for 29 states and increased for 22 states.

The last column in Table 4 shows the effect on each state's exports weighted by the export shares of the five regions. For most states (38), the effect of NAFTA was to increase exports. For 12 states, however, the effect was estimated to be negative. For one state (Montana) the estimated effect was zero.

Suggestive evidence for U.S. states indicates that NAFTA is associated with a declining distance of trade. Two pieces of evidence are available. First,

27 For details on these deliberations, see *North American Free Trade Agreement Arbitral Panel Established Pursuant to Chapter Twenty in the Matter of Cross-Border Trucking Services* (Hunter et al., 2001).

28 A companion article by Wall (2003) estimates the effects of NAFTA on trade flows between subnational regions within North America and between the same subnational regions and non-NAFTA regions.

29 Coughlin and Wall (2003) define regions for their NAFTA estimates differently than regions are defined in this paper. When using Coughlin and Wall's NAFTA estimates, their regional definitions are used.

## Table 4

### Estimated Percentage Change in Exports—Effect of NAFTA

| State | Mexico | Canada | Europe | Asia | Latin America | World |
|---|---|---|---|---|---|---|
| Alabama | 43.9 | 35.1 | –1.5 | –24.6 | 14.7 | 12.1 |
| Alaska | 55.1 | 35.4 | 10.5 | –0.9 | –22.0 | 3.6 |
| Arizona | 20.9 | 23.2 | 8.8 | 34.8 | –24.0 | 22.5 |
| Arkansas | 33.8 | 35.6 | –19.3 | 9.8 | 5.2 | 17.9 |
| California | 20.2 | 24.5 | –2.8 | 33.0 | 4.6 | 21.2 |
| Colorado | 12.3 | 17.2 | 6.6 | 59.0 | 3.2 | 28.5 |
| Connecticut | 11.5 | 14.5 | 8.3 | –10.6 | –14.5 | 4.2 |
| Delaware | 40.6 | –60.3 | 13.4 | 9.1 | 16.6 | –12.5 |
| District of Columbia | –2.9 | 42.2 | –40.7 | –9.1 | –18.8 | –15.0 |
| Florida | –10.2 | –6.2 | –8.9 | 3.2 | –4.2 | –4.4 |
| Georgia | 15.9 | 26.2 | 2.4 | 30.0 | 3.4 | 16.3 |
| Hawaii | –22.9 | –30.8 | 1.3 | –6.9 | –31.2 | –8.2 |
| Idaho | –21.3 | 9.4 | –14.3 | 41.8 | –37.2 | 15.2 |
| Illinois | 7.0 | 22.5 | –11.8 | 37.3 | 18.7 | 16.5 |
| Indiana | 3.6 | 42.8 | 9.3 | 7.9 | 0.3 | 25.9 |
| Iowa | 27.2 | 24.1 | 5.7 | 18.0 | 6.6 | 16.7 |
| Kansas | 3.3 | 42.0 | –5.6 | 27.3 | 1.4 | 21.9 |
| Kentucky | 8.0 | 62.0 | 10.8 | 14.6 | 43.7 | 35.4 |
| Louisiana | –11.3 | 9.7 | –13.2 | 24.0 | 4.4 | 6.3 |
| Maine | –10.0 | 10.3 | –2.6 | –2.5 | –17.9 | 1.8 |
| Maryland | 3.1 | –0.3 | –30.9 | 49.5 | 3.3 | 0.3 |
| Massachusetts | 13.7 | 23.9 | –4.9 | –8.4 | –14.9 | 1.2 |
| Michigan | 32.6 | –16.1 | –13.5 | 14.3 | –1.0 | –3.6 |
| Minnesota | –21.9 | 21.4 | –6.4 | 16.9 | –25.3 | 8.4 |
| Mississippi | 7.3 | –4.4 | –11.1 | –21.6 | –32.1 | –13.7 |
| Missouri | 4.3 | 18.1 | 34.6 | 2.0 | –3.1 | 16.5 |
| Montana | 54.1 | –5.7 | 18.1 | –23.8 | –36.9 | 0.0 |
| Nebraska | 64.4 | 27.6 | –10.7 | 19.4 | –7.7 | 21.5 |
| Nevada | –79.4 | 38.2 | 31.7 | –3.3 | –19.8 | 24.2 |
| New Hampshire | 33.4 | 14.1 | –14.7 | –10.7 | –35.3 | –2.2 |
| New Jersey | –1.1 | 20.6 | –9.1 | –0.4 | –8.1 | 2.0 |
| New Mexico | 62.8 | –9.5 | –13.9 | 43.9 | –26.5 | 37.2 |
| New York | –19.3 | 26.2 | –19.0 | –9.3 | –30.4 | –2.9 |
| North Carolina | 77.6 | 42.8 | 7.2 | –8.3 | 20.0 | 21.4 |
| North Dakota | 18.1 | 10.2 | 5.7 | –20.1 | –26.9 | 7.3 |
| Ohio | 5.0 | 20.0 | –11.7 | 8.9 | 5.5 | 10.6 |
| Oklahoma | 29.2 | –7.1 | –12.7 | 15.4 | 14.4 | 2.0 |
| Oregon | 24.5 | 5.7 | 9.0 | 34.7 | –0.8 | 23.1 |
| Pennsylvania | 1.6 | 26.6 | –1.5 | 6.0 | 5.8 | 12.0 |
| Rhode Island | –9.0 | 18.4 | –12.2 | –7.1 | –20.7 | –0.9 |
| South Carolina | 96.4 | 42.7 | –0.5 | 4.2 | 5.1 | 21.1 |
| South Dakota | 5.7 | 42.8 | 2.9 | –2.8 | –27.3 | 17.9 |
| Tennessee | 38.2 | 40.7 | –2.1 | 14.6 | 15.4 | 22.7 |
| Texas | 13.8 | 37.9 | 0.2 | 12.1 | –5.0 | 13.0 |
| Utah | 26.2 | –6.4 | 32.2 | –27.0 | 2.4 | 5.5 |
| Vermont | 19.8 | 8.0 | 27.1 | 45.9 | –24.3 | 18.8 |
| Virginia | 46.8 | 20.8 | 10.5 | –2.2 | 12.9 | 10.9 |
| Washington | –9.9 | –14.5 | –24.6 | 8.0 | –13.2 | –4.8 |
| West Virginia | –44.2 | 10.9 | –7.9 | 10.8 | –43.9 | –1.4 |
| Wisconsin | 38.7 | 23.3 | 10.1 | 16.0 | –7.9 | 16.9 |
| Wyoming | 52.8 | 11.8 | –47.2 | –22.2 | 7.0 | –4.0 |
| US total | 15.7 | 15.2 | –5.6 | 15.2 | –2.7 | 7.8 |

SOURCE: Coughlin and Wall (2003, Table 1C).

## Table 5

**Mean Distance of Trade (in Miles) for 1994-2002 Relative to Mean Distance of Trade for 1988-93**

| State | 1988-93 | 1994-2002 | Ratio of means |
|---|---|---|---|
| Alabama | 6,125 | 5,155 | 0.84* |
| Alaska | 13,702 | 12,771 | 0.93* |
| Arizona | 6,714 | 6,513 | 0.97 |
| Arkansas | 5,583 | 5,443 | 0.97 |
| California | 8,388 | 8,100 | 0.97 |
| Colorado | 7,042 | 7,148 | 1.02 |
| Connecticut | 5,373 | 5,108 | 0.95* |
| Delaware | 3,495 | 4,160 | 1.19* |
| District of Columbia | 5,093 | 5,881 | 1.15* |
| Florida | 3,604 | 3,440 | 0.95 |
| Georgia | 5,596 | 5,389 | 0.96 |
| Hawaii | 13,087 | 13,779 | 1.05 |
| Idaho | 8,641 | 8,368 | 0.97* |
| Illinois | 5,495 | 5,185 | 0.94 |
| Indiana | 5,062 | 4,202 | 0.83* |
| Iowa | 5,791 | 5,309 | 0.92* |
| Kansas | 6,130 | 5,860 | 0.96* |
| Kentucky | 5,434 | 4,875 | 0.90* |
| Louisiana | 6,737 | 6,362 | 0.94* |
| Maine | 5,351 | 5,599 | 1.05 |
| Maryland | 5,056 | 5,474 | 1.08* |
| Massachusetts | 5,607 | 5,591 | 1.00 |
| Michigan | 3,245 | 3,366 | 1.04* |
| Minnesota | 6,158 | 6,016 | 0.98* |
| Mississippi | 5,420 | 4,659 | 0.86* |
| Missouri | 4,507 | 4,326 | 0.96 |
| Montana | 5,325 | 4,189 | 0.79* |
| Nebraska | 7,059 | 6,830 | 0.97 |
| Nevada | 5,906 | 5,531 | 0.94 |
| New Hampshire | 5,110 | 4,846 | 0.95* |
| New Jersey | 5,117 | 5,085 | 0.99 |
| New Mexico | 7,027 | 8,881 | 1.26* |
| New York | 5,506 | 5,110 | 0.93* |
| North Carolina | 5,841 | 5,009 | 0.86* |
| North Dakota | 3,129 | 3,596 | 1.15* |
| Ohio | 4,733 | 4,273 | 0.90* |
| Oklahoma | 5,357 | 5,113 | 0.95 |
| Oregon | 9,411 | 9,248 | 0.98 |
| Pennsylvania | 5,177 | 4,832 | 0.93* |
| Rhode Island | 4,997 | 4,964 | 0.99 |
| South Carolina | 5,799 | 4,856 | 0.84* |
| South Dakota | 4,884 | 4,593 | 0.94 |
| Tennessee | 5,278 | 4,741 | 0.90* |
| Texas | 4,676 | 4,000 | 0.86* |
| Utah | 7,862 | 7,303 | 0.93 |
| Vermont | 3,253 | 4,402 | 1.35* |
| Virginia | 5,700 | 5,527 | 0.97* |
| Washington | 9,525 | 9,337 | 0.98 |
| West Virginia | 5,491 | 5,640 | 1.03 |
| Wisconsin | 5,225 | 4,947 | 0.95* |
| Wyoming | 8,143 | 7,027 | 0.86* |

NOTE: *Using a 10 percent significance level, the hypothesis of equal means for the two periods is rejected.

Table 5 shows the average distance of trade by state for two periods, 1988-93 and 1994-2002. This split reflects the official beginning of NAFTA in 1994.

A comparison of the means for the two periods shows 40 states with a declining distance of trade and 11 with an increasing distance of trade. This evidence simply reflects the fact that the distance of trade has trended downward for most states. The last column in Table 5 shows the ratio of the means for each state for the two periods. Values exceeding 1 indicate an increasing distance of trade, while values less than 1 reflect a declining distance of trade. Of the 40 states with a decreasing distance of trade, Montana and Wyoming stand out because their distance of trade decreased by more than 1,000 miles between the two periods. Using a 10 percent significance level, 23 of these 40 states had a statistically significant lower mean for 1994-2002 relative to 1988-93. Of the 11 states with an increasing distance of trade, New Mexico and Vermont stand out because their distance of trade increased by more than 1,000 miles between the two periods. Of these 11 states, 7 had a statistically significant higher mean for 1994-2002 relative to 1988-93.

The second piece of evidence uses the estimates of Coughlin and Wall (2003). Using the estimates for the impact of NAFTA on state exports to five regions, I calculate a distance-weighted measure of NAFTA's effect on each state. For each state, this measure is calculated as follows: Multiply the NAFTA effect estimated by Coughlin and Wall by the share of a state's exports to that region; divide by the distance from the state to the region; and then sum over the five regions.[30] Larger values of this measure indicate that NAFTA has had larger impacts on trade with nearby regions (i.e., Canada, Mexico, and Latin America) relative to distant regions (i.e., Europe and Asia). In turn, larger values of this measure should be associated with larger percentage declines in a state's distance of trade.[31] In fact, the simple correlation coefficient between this distance-weighted measure of NAFTA and the percentage change in a state's distance of trade is –0.33, which is statistically significant at the 5 percent level. In other words, across states, larger values of the overall, distance-weighted effect of NAFTA are associated with larger declines in the distance of trade.

## Uneven Income Growth

The last usual suspect that I examine is the possibility that the growth of U.S. trading partners has evolved in a manner that would cause demand for U.S. exports to increase faster at proximate as opposed to distant locations. Previous research has explored the connection between income growth and state exports by using two approaches. One approach uses regression analysis to estimate the extent to which foreign incomes affect state exports. These studies, exemplified by Erickson and Hayward (1991), Cronovich and Gazel (1998), and Coughlin and Wall (2003), find a strong, statistically significant relationship.

A second approach analyzes the connection between foreign incomes and state exports using shift-share analysis. Shift-share analyses separate the change in a state's exports into potentially meaningful components, one of which is the destination of a state's exports. Gazel and Schwer (1998) find that destination is as important as any other factor, such as the industry composition of exports, in accounting for state export performance between 1989 and 1992.[32]

To examine the impact of uneven income growth, I first examine the change in growth in the major geographic destinations for U.S. exports.[33] Table 6 is constructed using compound annual GDP growth during each of the five-year periods: 1987-92, 1992-97, and 1997-2002.[34] The GDP growth calculations, then, essentially reflect the same time periods as those used in Table 1. Focusing on 1997-2002, GDP grew relatively more rapidly in Mexico and Canada than in the other regions. In light of the

[30] In equation form, the calculation is $DISNAFTA_i = \Sigma(NAFTA_{ij} \times Share_{ij})/Distance_{ij}$, where $i$ indicates a specific state, $j$ indicates a specific export region (i.e., Canada, Mexico, Europe, Asia, and Latin America), *NAFTA* is the estimated change in exports, *Share* is the percentage of a state's exports destined for a specific export region, and *Distance* is the distance from the state to a specific export region.

[31] An illustration of the reasoning using two states might be useful. Assume one state's exports throughout the world were completely unaffected by NAFTA. Meanwhile, assume the other state's exports to its NAFTA partners increased substantially and its exports to the rest of the world were unaffected. In the preceding scenario one would expect the state affected by NAFTA to show a larger decline in its distance of trade than the state unaffected by NAFTA.

[32] Coughlin and Pollard (2001), however, find that the competitive effect dominates both the industry mix and destination effects in accounting for state export growth between 1988 and 1998.

[33] Note that the regions discussed here, in Table 1 and in Table 6, are not composed of the same countries as the regions associated with the NAFTA measures. See Coughlin and Wall (2003) for a discussion on the construction of the NAFTA regions.

[34] This was calculated using the top 30 export markets for which GDP is available.

**Table 6**

**Compound Annual GDP Growth by Major Geographic Destination (%)**

| | 1987-92 | 1992-97 | 1997-2002 |
|---|---|---|---|
| Canada | 3.0 | –0.7 | 1.6 |
| Mexico | 17.0 | –2.2 | 10.2 |
| Latin America and the Caribbean | 4.9 | 9.5 | –10.0 |
| Europe | 5.6 | –0.6 | –0.4 |
| Asia | 0.6 | 2.5 | –1.5 |
| Africa | –0.7 | 1.7 | –1.8 |
| Oceania | 3.2 | 4.5 | –1.8 |
| World | 3.4 | 1.3 | –1.2 |

major importance of these two trading partners, it is not surprising that the distance of trade for most states tended to be lower for 1997-2002 relative to earlier in my sample. The poor economic performance in Latin America and the Caribbean likely tempered some of the decline in the distance of trade stemming from the relatively rapid growth in Mexico and Canada.

Second, I construct a distance-weighted measure of the growth of each state's trading partners. This measure is calculated analogously to the distance-weighted measure of NAFTA used in the preceding section.[35] Larger values of this measure indicate relatively faster growth for nearby trading partners than for distant trading partners. Thus, this measure should be related negatively to the percentage changes in the distance of trade. The simple correlation coefficient is –0.31, which is statistically significant at the 5 percent level.

## CONCLUSION

The preceding analysis has addressed two basic questions concerning the geography of state exports. First, how has the geographic distribution of state exports changed? Second, which changes in the economic environment appear to account for the observed changes in the geographic distribution of state exports?

Overall, the geographic distribution of exports has changed so that trade has become relatively more intense with nearby as opposed to distant countries. State trade shares with Mexico, Canada, and Latin America and the Caribbean have increased, while shares with Europe, Asia, Africa, and Oceania have decreased. Reflecting the change in trade shares, the distance of trade for the aggregate of states has declined. However, all states did not experience similar changes. For example, 40 states experienced declining distance of trade, while 11 states experienced an increasing distance of trade.

Three related changes in the economic environment were examined. Suggestive evidence indicates that all three changes might have contributed to the observed changes in the geographic distribution of state exports and, in turn, overall U.S. exports. Declining costs of transportation over land have tended to favor state exports to Canada and Mexico relative to trade with distant locations. Trade with Canada and Mexico has also been propelled by NAFTA. Coughlin and Wall (2003) estimated the effect of NAFTA on a state-by-state basis. NAFTA was found to have had different effects across states. These differential effects were found to be related to the changes in the distance of trade experienced by states. Finally, income growth by nearby trading partners was found to be related to the changes in the distance of trade experienced by states.

One issue that remains for future research is the extent to which specific industries contribute to the declining distance of trade. Berthelon and Freund (2004) suggest that technological changes might be stimulating production fragmentation within regions. Thus, for a number of industries, changing technology that enhances the advantages of proximity might be an important reason for the declining distance of trade.

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# Monetary Policy and Asset Prices: A Look Back at Past U.S. Stock Market Booms

Michael D. Bordo and David C. Wheelock

Large swings in asset prices and economic activity in the United States, Japan, and other countries over the past several years have brought new attention to the linkages between monetary policy and asset markets. Monetary policy has been cited as both a possible cause of asset price booms and a tool for defusing those booms before they can cause macroeconomic instability. Economists and policymakers have focused on how monetary policy might cause an asset price boom or turn a boom caused by real phenomena, such as an increase in aggregate productivity growth, into a bubble. They have also addressed how monetary policy authorities should respond to asset price booms.

This article examines the economic environments in which past U.S. stock market booms occurred as a first step toward understanding how asset price booms come about. Have past booms reflected real economic growth and advances in productivity, expansionary monetary policy, inflation, or simply "irrational exuberance" that defies explanation? We use a simple metric to identify several episodes of sustained, rapid rises in equity prices in the 19th and 20th centuries and then assess both narrative and quantitative information about the growth of real output, productivity, the price level, the money supply, and credit during each episode. Across some two hundred years, we find that two U.S. stock market booms stand out in terms of their length and rate of increase in market prices—the booms of 1923-29 and 1994-2000. In general, we find that booms occurred in periods of rapid real growth and advances in productivity. We find, however, no consistent relationship between inflation and stock market booms, though booms have typically occurred when money and credit growth were above average. Finally, contrary to conventional wisdom, we find that wars have not always been good for the market.

This article begins by reviewing relevant issues concerning the links between monetary policy and asset prices. The following section presents a monthly time series index of U.S. equity prices spanning two hundred years and identifies boom episodes. Subsequent sections present a descriptive history of U.S. stock market booms since 1834, summarize our findings, and offer conclusions.

## MONETARY POLICY ISSUES

The literature on the linkages between monetary policy and asset markets is vast. Here, we focus on two issues—the role of asset prices in the transmission of monetary policy to the economy as a whole and the appropriate response of monetary policy to asset price booms. The first concerns the extent to which monetary policy might cause an asset price boom. The second concerns the circumstances in which monetary policymakers should attempt to defuse asset price booms.

### *Asset Prices and the Transmission Mechanism*

There are many views about how monetary policy might cause an asset price boom. For example, a traditional view focuses on the response of asset prices to a change in money supply. In this view, added liquidity increases the demand for assets, thereby causing their prices to rise, stimulating the economy as a whole. A second view, voiced by Austrian economists in the 1920s and more recently by economists of the Bank for International Settlements (BIS), argues that asset price booms are more likely to arise in an environment of low, stable inflation. In this view, monetary policy can encourage

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asset price booms simply by credibly stabilizing the price level. Still another view, coming from the dynamic general-equilibrium macroeconomics literature, argues that asset price bubbles can result from the *failure* of monetary policy to credibly stabilize the price level.

The liquidity view has a long history. Some early Keynesian IS-LM models, such as that of Metlzer (1951), had central bank operations affecting stock prices directly. A next generation of models, variants of which are presented in Friedman and Schwartz (1963b), Tobin (1969), and Brunner and Meltzer (1973), introduce a broader range of assets into the traditional Keynesian liquidity mechanism. In these models, central bank operations that increase liquidity will cause the prices of assets that comprise the private sector's portfolio, including equities and real estate, to rise and thereby lower their returns. Substitution from more- to less-liquid assets occurs as the returns on the former decline relative to the latter. The impact of expansionary monetary policy will be apparent first in the price of short-term government securities; then longer-term securities; then other assets such as stocks, real estate, and commodities such as gold; and finally in the overall price level. Thus, this view sees rising asset prices as a possible harbinger of future inflation.

The Austrian-BIS view argues that an asset price boom, whatever its fundamental cause, can degenerate into a bubble if monetary policy passively allows bank credit to expand to fuel the boom. This view holds that, unless policymakers act to defuse a boom, a crash will inevitably follow that in turn may cause a downturn in economic activity. The Austrians tended to equate rising asset prices with general price inflation. For example, although the level of U.S. consumer prices was virtually unchanged between 1923 and 1929, the Austrians viewed the period as one of rapid inflation fueled by loose Federal Reserve policy and excessive growth of bank credit (e.g., Rothbard, 1983).[1]

This view has carried forward into the modern discussion of asset price booms. Two issues are relevant. The first is whether the price index targeted by the central bank should include asset prices. Alchian and Klein (1973) contend that a theoretically correct measure of inflation is the change in the price of a given level of utility, which includes the present value of future consumption. An accurate estimate of inflation, they argue, requires a broader price index than one consisting of only the prices of current consumption goods and services. To capture the price of future consumption, Alchian and Klein (1973) contend that monetary authorities should target a price index that includes asset prices. Bryan, Cecchetti, and O'Sullivan (2002) concur, arguing that because it omits asset prices (especially housing prices), the consumer price index (CPI) seriously understated inflation during the 1990s.[2]

A second connection of the Austrian view to the recent experience concerns the issue of "financial imbalances," which Borio and Lowe (2002) define as rapid growth of credit in conjunction with rapid increases in asset prices and, possibly, investment.[3] Borio and Lowe (2002) argue that a buildup of such imbalances can increase the risk of a financial crisis and macroeconomic instability. They construct an index of imbalances based on a credit gap (deviations of credit growth from trend), an equity price gap, and an output gap to identify incipient asset price declines that lead to significant real output losses, and they advocate its use as a guide for proactive policy action. Eichengreen and Mitchener (2003) find that a similar index for the 1920s helps explain the severity of the Great Depression.

Borio and Lowe (2002) argue that low inflation can promote financial imbalances, regardless of the underlying cause of an asset price boom. For example, by generating optimism about the macroeconomic environment, low inflation might cause asset prices to rise more in response to an increase in productivity growth than they otherwise would. Similarly, an increase in demand is more likely to cause asset prices to rise if the central bank is viewed as credibly committed to price stability. A commitment to price stability that is viewed as credible, Borio and Lowe (2002) argue, will make product prices less sensitive and output and profits more sensitive in the short run to an increase in demand. At the same time, the absence of inflation may cause monetary policymakers to delay tightening policy as demand pressures build. Thus, Borio and Lowe

[1] See Laidler (2003) and the references therein for more on the Austrian view.

[2] See also Goodhart and Hofmann (2000). Filardo (2000), by contrast, concludes that including housing prices in an index of inflation would not substantially improve U.S. economic performance.

[3] See also Borio, English, and Filardo (2003) and Borio and White (2003). See Laidler (2003) and Eichengreen and Michener (2003) for discussion of the similarities and differences between the modern "imbalance" view and the Austrian emphasis on bank credit induced "forced saving" as the cause of "overinvestment" in the 1920s that led to the stock market crash and the Great Depression.

(2002, pp. 30-31) contend that "these endogenous responses to credible monetary policy [can] increase the probability that the latent inflation pressures manifest themselves in the development of imbalances in the financial system, rather than immediate upward pressure in higher goods and services price inflation."

The possibility that monetary policy can produce asset price bubbles has also been studied extensively in equilibrium rational-expectations models. In such models, poorly designed monetary policies, such as the use of interest rate rules without commitment to a steady long-run inflation rate, can lead to self-fulfilling prophesies and asset price bubbles. Such outcomes are less likely, Woodford (2003) argues, if monetary policymakers follow a clear rule in which the interest rate target is adjusted sufficiently to stabilize inflation. The theoretical literature thus suggests that consideration of the monetary policy environment may be crucial to understanding why asset booms come about.

## Proactive Policy in Response to Asset Price Booms?

The appropriate response, if any, of monetary policy to an asset price boom was the subject of extensive debate during the U.S. stock market boom of 1994-2000 and the recession that followed. Since periods of explosive growth in asset prices have often preceded financial crises and contractions in economic activity, some economists argue that by defusing asset price booms, monetary policy can limit the adverse impact of financial instability on economic activity. The likelihood of a price collapse and subsequent macroeconomic decline might, however, depend on why asset prices are rising in the first place. Many analysts believe that asset booms do not pose a threat to economic activity or the outlook for inflation so long as they can be justified by realistic prospects of future earnings growth. On the other hand, if rising stock prices reflect "irrational exuberance," they may pose a threat to economic stability and, in the minds of many, justify a monetary policy response to encourage market participants to revalue equities more realistically.

The traditional view holds that monetary policy should react to asset price movements only to the extent that they provide information about future inflation. This view holds that monetary policy will contribute to financial stability by maintaining stability of the price level (Bordo, Dueker, and Wheelock, 2002, 2003; Schwartz, 1995), and that financial imbalances or crises should be dealt with separately by regulatory or lender-of-last-resort policies (Schwartz, 2002).[4]

Many economists do not accept the traditional view, at least not entirely. Smets (1997), for example, argues that monetary policy tightening is optimal in response to "irrational exuberance" in financial markets (see also Detken and Smets, 2003). Similarly, Cecchetti et al. (2000) contend that monetary policy should react when asset prices become misaligned with fundamentals. Bernanke and Gertler (2001) express doubt that policymakers can judge reliably whether asset prices are being driven by "irrational exuberance" or that an asset price collapse is imminent. Cecchetti (2003) replies, however, that asset price misalignments are no more difficult to identify than other components of the Taylor rule, such as potential output.

Bordo and Jeanne (2002a,b) offer a novel argument in support of a monetary policy response to asset price booms. They argue that preemptive actions to defuse an asset price boom can be regarded as insurance against the high cost of lost output should a bust occur. Bordo and Jeanne contend that policymakers should attempt to contain asset price misalignments when the risk of a bust (or the consequences of a bust) is large or when the cost of defusing a boom is low in terms of foregone output. Bordo and Jeanne show that a tension exists between these two conditions. As investors become more exuberant, the risk associated with a reversal in market sentiment increases, but leaning against the wind of investor optimism requires more costly monetary actions. Thus, the monetary authorities must evaluate both the probability of a costly crisis and the extent to which they can reduce this probability.

## FOMC Deliberations About the Stock Market

The debate about the appropriate response of monetary policy to asset price booms has not taken place solely in professional journals and working papers. The implications of rising asset prices became an increasingly important component of Federal Reserve policy discussions during the U.S.

[4] Bernanke and Gertler (1999, 2001) present the traditional view in the context of a Taylor rule. Bullard and Schaling (2002), Schinasi and Hargraves (1993), and White (2004) are among other studies supporting the traditional view.

stock market boom of 1994-2000. Cecchetti (2003) presents evidence suggesting that movements in equity prices help explain adjustments in the Federal Open Market Committee's (FOMC's) federal funds rate target during this period.[5]

Transcripts of FOMC meetings in 1996 and 1997 reveal that Fed officials focused on a potential "wealth effect" of rising stock prices on consumer confidence and spending and worried that a sudden reversal of equity prices could cause real economic activity to decline sharply. For example, at a meeting on March 26, 1996, Chairman Greenspan stated that "It's hard to believe that if any series of adverse developments were to occur, the market would not come down rather substantially and reverse the wealth effect. That probably would dampen economic activity quite substantially" (FOMC transcript, March 26, 1996, p. 29).

Policymakers grew increasingly concerned as equity prices continued to rise, and the FOMC discussed how to respond. At a Committee meeting on February 4-5, 1997, Chairman Greenspan stated that the prevailing level of equity prices, along with unusually narrow interest rate credit spreads, "suggest[s] that product prices alone should not be the sole criterion [for conducting monetary policy] if we are going to maintain a stable, viable financial system whose fundamental goal…is the attainment of maximum sustainable economic growth" (FOMC transcript, February 4-5, 1997, p. 103).

Greenspan saw a conundrum in the use of monetary policy to defuse an asset price boom, however, and expressed the view that stock market booms are more likely to occur when inflation is low:

> We have very great difficulty in monetary policy when we confront stock market bubbles. That is because, to the extent that we are successful in keeping product price inflation down, history tells us that price-earnings ratios under those conditions go through the roof. What is really needed to keep stock market bubbles from occurring is a lot of product price inflation, which historically has tended to undercut stock markets almost everywhere. There is a clear tradeoff. If monetary policy succeeds in one, it fails in the other. Now, unless we have the capability of playing in between and managing to know exactly when to push a little here and to pull a little there, it is not obvious to me that there is a simple set of monetary policy solutions that deflate the bubble. (FOMC transcript, September 24, 1996, pp. 30-31)

We next turn to the history of past U.S. stock market booms to try to identify the macroeconomic environments in which booms have occurred as a first step toward identifying lessons for the conduct of monetary policy in these cases.

## *Historical Data on the U.S. Stock Market*

We focus on the stock market because long-term data on the prices of other assets, e.g., real estate, are not available and, moreover, because stock prices are often the focus of policy concerns about the causes and effects of booms and busts (e.g., during the late 1990s and the 1920s).[6] Our interest is with the performance of broad stock market averages, not in the performance of individual stocks or groups of stocks. Booms, of course, are typically centered in particular sectors—usually the "high-tech" sectors of the day—but the booms that capture the attention of macroeconomists and policymakers are broadly based. In the 1990s, computer, telecommunications, and internet stocks were at the epicenter of the stock market boom. The stock prices of a wide range of companies also rose sharply, however, and the broader market averages, such as the Standard and Poor's (S&P) 500 and the Wilshire 5000, all increased substantially, though not as much as the NASDAQ, which quintupled (see Figure 1 for comparison of the S&P 500 and NASDAQ from 1990 to 2003).

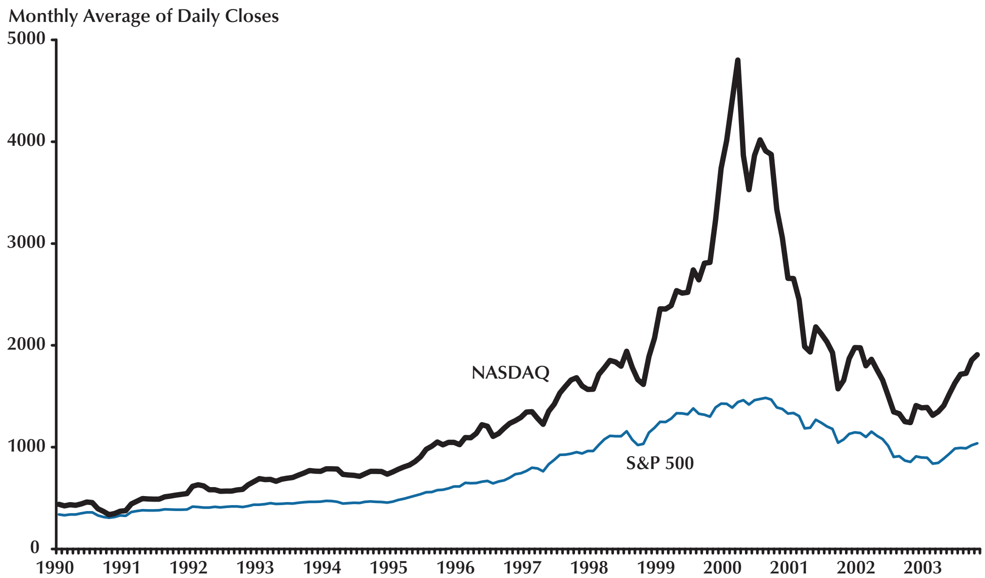
Schwert (1990) constructed a continuous monthly stock market index for the United States for the period 1802-70, linking indices created by Smith and Cole (1935) for 1802-62 and Macaulay (1938) for 1863-70. Banks were the first large corporate enterprises in the United States, and for 1802-34, the stock market index consists of only bank stocks. Railroads, the largest corporate sector throughout much of the 19th century, got their start in the 1830s. For 1835-45, the stock market index comprises both bank and railroad stock prices, and for 1846-70 only railroad stocks.

[5] Additional evidence of a monetary policy response to the stock market is presented by Rigobon and Sack (2003). Hayford and Malliaris (2004), by contrast, find that the Fed did not respond to the market.

[6] Helbling and Terrones (2004) examine both housing and stock market booms for several countries since 1970.

## Figure 1

**S&P 500 and NASDAQ Composite Indices, January 1990–October 2003**




## Figure 2

**Schwert-S&P Stock Price Index, 1802-2002**
**Actual and Nine-Year Trailing Moving Average**

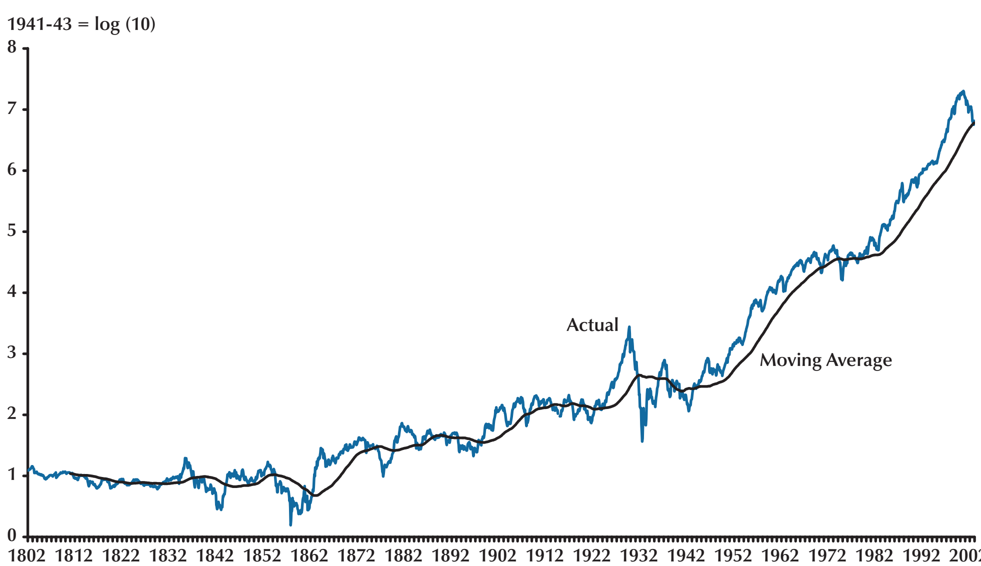


**Table 1**

**U.S. Stock Market Booms: Alternative Starting Dates**

| Boom beginning in trough | Avg. % change in index during boom (months duration) | Beginning when local peak surpassed | Avg. % change in index during boom (months duration) | Beginning when global peak surpassed | Avg. % change in index during boom (months duration) | Boom ending month |
|---|---|---|---|---|---|---|
| Feb 1834 | 35.06 (16) | Apr 1834 | 26.45 (14) | Apr 1834 | 26.45 (14) | May 1835 |
| Jan 1843 | 23.35 (36) | Dec 1843 | 12.31 (25) | Dec 1852 | NA | Dec 1845 |
| Nov 1848 | 9.80 (50) | May 1852 | 20.05 (7) | Dec 1852 | NA | Dec 1852 |
| Jul 1861 | 40.20 (33) | Oct 1862 | 37.28 (20) | May 1863 | 27.24 (10) | Mar 1864 |
| Apr 1867 | 8.83 (61) | Jan 1868 | 7.05 (52) | Jan 1868 | 7.05 (52) | Apr 1872 |
| Jun 1877 | 22.58 (49) | Oct 1879 | 21.13 (21) | Apr 1880 | 21.22 (15) | Jun 1881 |
| Aug 1896 | 20.74 (33) | Sep 1896 | 19.47 (32) | Dec 1900 | NA | Apr 1899 |
| Sep 1900 | 22.02 (25) | Nov 1900 | 17.76 (23) | Dec 1900 | 15.34 (22) | Sep 1902 |
| Oct 1903 | 16.74 (36) | Mar 1905 | 12.82 (19) | Mar 1905 | 12.82 (19) | Sep 1906 |
| Aug 1896 | 10.33 (122) | Sep 1896 | 9.92 (121) | Dec 1900 | 7.32 (70) | Sep 1906 |
| Oct 1923 | 23.70 (72) | Nov 1924 | 25.12 (59) | Jan 1925 | 23.97 (45) | Sep 1929 |
| Mar 1935 | 41.32 (24) | Aug 1935 | 30.28 (19) | Sep 1954 | NA | Feb 1937 |
| Apr 1942 | 21.92 (50) | Dec 1944 | 25.78 (18) | Sep 1954 | NA | May 1946 |
| Jun 1949 | 18.08 (44) | Jan 1950 | 15.17 (37) | Sep 1954 | NA | Jan 1953 |
| Sep 1953 | 26.87 (35) | Mar 1954 | 26.88 (29) | Sep 1954 | 24.85 (23) | Jul 1956 |
| Jun 1949 | 18.27 (86) | Jan 1950 | 16.95 (79) | Sep 1954 | 24.85 (23) | Jul 1956 |
| Jun 1962 | 14.79 (44) | Sep 1963 | 10.84 (29) | Sep 1963 | 10.84 (29) | Jan 1966 |
| Jul 1984 | 26.04 (38) | Jan 1985 | 25.96 (32) | Jan 1985 | 25.96 (32) | Aug 1987 |
| Dec 1987 | 11.57 (74) | Jul 1989 | 8.34 (55) | Jul 1989 | 8.34 (55) | Jan 1994 |
| Apr 1994 | 19.64 (77) | Feb 1995 | 21.23 (67) | Feb 1995 | 21.23 (67) | Aug 2000 |

After the Civil War, the U.S. industrial sector grew to include large publicly traded manufacturers of steel, petroleum products, chemicals, and other goods, and available indices of stock prices reflect the increasing breadth of the market. We link Schwert's (1990) index for 1802-70 to the Cowles (1939) index of New York Stock Exchange prices covering 1871-1920 and then to the S&P composite index. A consistent S&P series is available from 1921 to the present modern form, the S&P 500 index.[7] Figure 2 plots the entire index, from 1802 to 2002.[8]

## *Identifying Booms*

Our objective is to describe the macroeconomic environments in which sustained, rapid rises in stock prices have occurred. Over our entire sample, two boom episodes stand out, both in terms of their length and rate of advance in the market index: the bull markets of 1923-29 and 1994-2000. The rate of advance in the market index has been faster at other times, but only for short periods. Similarly, there have been other long bull markets, but none with such a large average rate of increase in the market index. Since the bull market of the 1920s stands out, we examine both the macroeconomic environment in which that boom occurred and the debate it generated among monetary policymakers. We also examine other episodes of rapid, sustained increases in the stock market index, however, in our attempt to identify environmental characteristics of stock market booms in general.

[7] Data for 1871-1920 are from the National Bureau of Economic Research macro-history database (series m11025a), and those for 1921-2002 are from Haver Analytics. Alternative indices are available, e.g., the Dow Jones Industrial Average, which began in 1895, but the episodes of "boom" and "bust" that appear in one index are common to all of the alternative broad indices.

[8] The New York Stock Exchange was closed during August-November 1914 and, hence, there are no index values for those months.

There is, of course, no precise empirical definition of an asset price boom, and researchers have imposed a number of filters to identify specific episodes that they then define as booms. We begin by using the methodology of Pagan and Sossounov (2003) to identify sustained periods of rising stock prices. Beginning in 1834, we identify the peak and the trough months for the market within a rolling 25-month window.[9] We require that peaks and troughs alternate, and so we eliminate all but the highest (lowest) of peaks (troughs) that occur before a subsequent trough (peak). Finally, we identify booms as periods lasting at least three years from trough to peak. Table 1 lists all such booms in our data, plus a few shorter episodes of exceptional increase in the market index, such as February 1834–May 1835. The table also lists a few periods that include two or more consecutive booms that were interrupted by short market declines and that might be better thought of as a single episode. For each period, the table also lists the average, annualized increase in the index during the boom period, i.e., from the month following the trough to the peak month.

One might question whether stock market booms should be defined to include recoveries from prior stock market declines. Indeed, some of the booms listed in Table 1 include long periods in which the market average remained below a prior peak. Hence, for each boom, we also indicate the month in which the previous (local) peak was reached, as well as the month in which the previous all-time market (global) peak was reached.[10] For each episode, we report the average, annualized increase in the index from the month following the attainment of both the prior local and global peaks to the new peak month. Clearly, a few sustained booms, such as that of July 1861–March 1864, involved several months in which the market was merely recovering to a prior peak (or to the prior all-time high). Indeed, a few booms ended without reaching a prior global peak. In general, the average increase in the market index was larger during the recovery phase of booms than during the phase in which the market index exceeded its prior high. Interestingly, two exceptions are the booms of the 1920s and of the late 1990s, suggesting again that these two booms were unique in character as well as magnitude.

Some studies define booms as sustained periods of increase in an asset price index above a trend growth rate (e.g., Bordo and Jeanne, 2002a; Detken and Smets, 2003). Figures 2 through 4 plot values of our stock price index alongside a nine-year trailing moving average of the index. From these charts, episodes when the market average increased (or decreased) rapidly relative to its recent trend are evident. Booms are evident in the mid-1830s, during the Civil War, from about 1879 to 1881, and, with interruptions, from about 1896 to 1906. The bull market of the 1920s is clearly evident, as is the rise from 1994 to 2000. In addition, the market advanced well above trend in the early 1950s and again from about 1984 to 1987.

Figure 5 plots the "real" (i.e., inflation-adjusted) stock market index and nine-year trailing moving average for 1924-2002. In theory, stock prices should not be affected by inflation that is anticipated.[11] Nevertheless, this plot illustrates more clearly that the bull markets of the 1920s and 1994-2000 stand out as exceptional periods of sustained, large increases in real as well as nominal stock prices. The real stock market index also rose substantially during the mid-1950s and between 1984 and 1987. Thus, regardless of how one looks at the data, the same boom episodes stand out.

## The Economic Environment of Booms

Table 2 reports information about the growth rates of labor productivity, real gross domestic product (GDP), industrial production, money stock, bank credit, and the price level during the boom episodes identified in Table 1. Here we define the start of a boom as the month following a market trough. For comparison, we also report growth rates of these variables over longer periods. Unfortunately, few macroeconomic data exist for early boom periods, and what data there are usually consist of annual

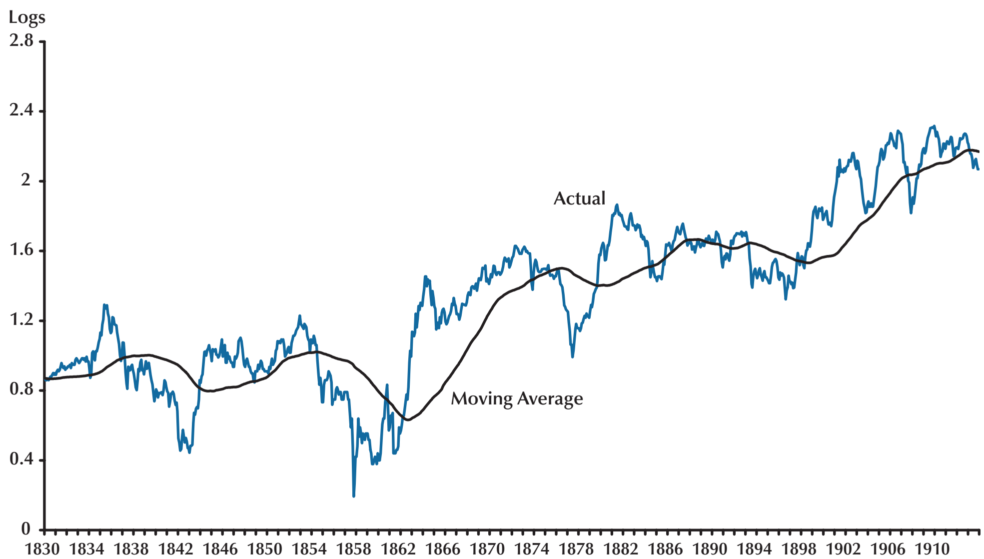
[9] We begin with 1834 because the stock market index before that year comprised only a small number of bank stocks, and, as shown in Figure 2, there appear to have been no large movements in the index before then.

[10] Helbling and Terrones (2004) use a similar approach in their cross-country study of stock market and real estate booms since 1970.

[11] The traditional capital asset pricing model posits that the current market price of a stock will equal the present discounted value of the expected dividend stream to the stockholder. Expected inflation should not affect the current price of the stock because even though expected inflation may increase the nominal dividend stream, the relevant interest rate for discounting those earnings also will reflect the expected inflation. Unanticipated inflation can, of course, wreak havoc with an investor's ex post real return on asset holdings, as occurred during the 1970s.

## Figure 3

**Stock Price Index, 1830-1913**
**Actual and Nine-Year Trailing Moving Average**




## Figure 4

**S&P Stock Price Index, 1922-2002**
**Actual and Nine-Year Trailing Moving Average**

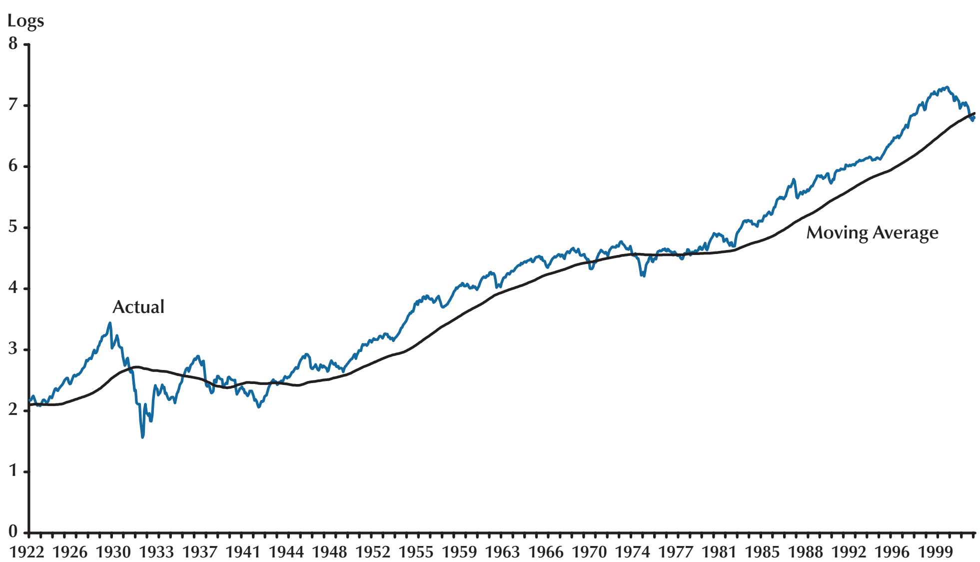
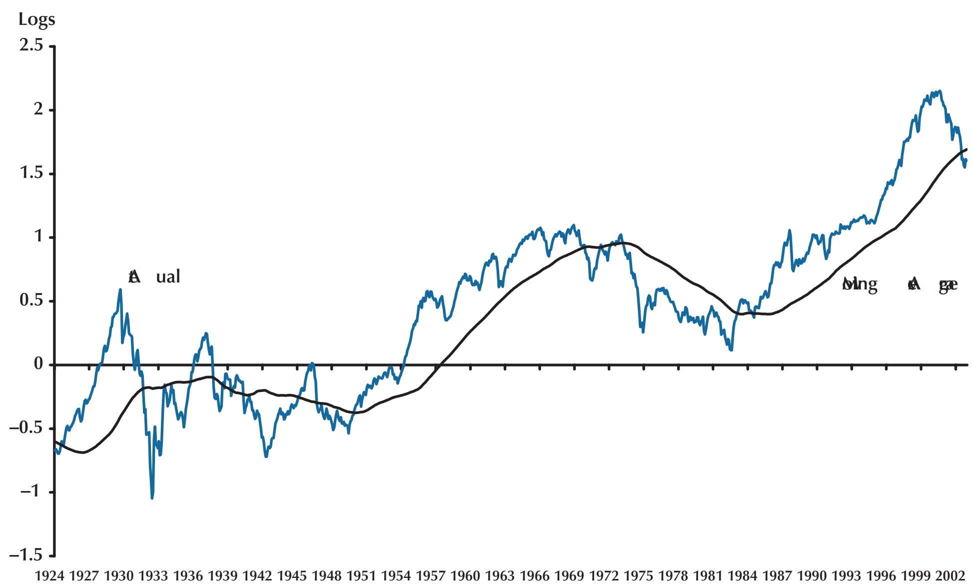


**Figure 5**

**Real Stock Price Index and Nine-Year Trailing Moving Average, 1924-2002**




observations. It appears, however, that market booms generally occurred during periods of relatively rapid growth of output and productivity. Pre-World War II booms also tended to occur during periods of above-average growth in the money stock, bank credit, and, sometimes, the price level. The growth rates of the money stock, bank credit, and the price level were not above average during the boom of 1923-29, however, nor during most post-World War II booms.

We next examine specific historical episodes in more detail. Obviously, not every episode identified in Table 1 deserves attention. From looking closely at a few episodes, however, we identify certain characteristics about the environments in which booms have occurred.

## Antebellum Stock Market Booms

The stock market booms of the 19th century were closely associated with the development of the nation's infrastructure—first canals and steamships, then railroads.

**1834-35.** Schwert's (1990) stock market index for this period combines indices of bank and railroad stocks from Smith and Cole (1935), with more weight put on the railroad stock index. Smith and Cole (1935) document a close relationship between public land sales and railroad stock prices in 1834-35, though stock prices peaked and began to fall before land sales started to decline in 1836 (p. 82). The close correlation between land sales and railroad stock prices throughout the antebellum period led Smith and Cole to conclude that "both series… may be regarded as reflecting a common element—that of the well-known speculative spirit of the country" (p. 82).

Federal government land sales rose from under \$2 million a year in the 1820s to \$5 million in 1834, \$15 million in 1835, and \$25 million in 1836. The land-sales and stock market booms occurred during a period of commodity price inflation. Temin (1969, p. 92) argues that the land boom was sparked by a sharp increase in the price of cotton, which rose some 50 percent during 1834 alone. The money stock increased sharply in 1835-36, spurred by large inflows of Mexican silver, which increased the growth rate of the monetary base (Temin, 1969, pp. 68-69).[12] It appears from limited data that the boom also occurred during a period of fairly strong growth of real economic activity. Smith and Cole's (1935, p. 73) index of the volume of trade shows a 14 percent rise in domestic trade in 1834-35 and even larger percentage gains in exports in 1835-36. Davis's

[12] At the time, the United States was on a bimetallic—gold and silver—standard. An increase in British investment in U.S. securities, coupled with a decline in silver exports to China, caused the inflow of Mexican silver to increase the monetary base.

## Table 2

### The Macroeconomic Environment of U.S. Stock Market Booms

| Trough month | Peak month | Avg. % change stock index | Avg. % change productivity | Avg. % change money stock |
|---|---|---|---|---|
| Feb 1834 | May 1835 | 35.06 | NA | 6.58 |
| Jan 1843 | Dec 1845 | 23.35 | NA | 16.57 |
| Nov 1848 | Dec 1852 | 9.80 | NA | 11.65 |
| Jul 1861 | Mar 1864 | 40.20 | NA | NA |
| Apr 1867 | Apr 1872 | 8.83 | NA | 4.00 |
| Jun 1877 | Jun 1881 | 22.58 | 1.20 | 11.93 |
| Aug 1896 | Apr 1899 | 20.74 | 3.44 | 12.38 |
| Sep 1900 | Sep 1902 | 22.02 | 2.30 | 12.10 |
| Oct 1903 | Sep 1906 | 16.74 | 3.16 | 8.47 |
| Aug 1896 | Sep 1906 | 10.33 | 2.57 | 9.88 |
| Oct 1923 | Sep 1929 | 23.70 | 2.08 | 3.93 |
| Mar 1935 | Feb 1937 | 41.32 | 2.49 | 10.93 |
| Apr 1942 | May 1946 | 21.92 | 1.90 | 17.91 |
| Jun 1949 | Jan 1953 | 18.08 | 3.86 | 3.75 |
| Sep 1953 | Jul 1956 | 26.87 | 1.69 | 2.85 |
| Jun 1949 | Jul 1956 | 18.27 | 2.71 | 3.30 |
| Jun 1962 | Jan 1966 | 14.79 | 3.68 | 7.83 |
| Jul 1984 | Aug 1987 | 26.04 | 1.54 | 7.37 |
| Dec 1987 | Jan 1994 | 11.57 | 1.62 | 3.43 |
| Apr 1994 | Aug 2000 | 19.64 | 1.98 | 5.13 |
| **Comparison periods** | | | | |
| Jan 1834 | Dec 1859 | –0.62 | NA | 5.93 |
| Jan 1866 | Dec 1913 | 2.31 | 1.30† | 5.71‡ |
| Jan 1919 | Dec 1940 | 3.99 | 2.05 | 3.29 |
| Jan 1946 | Dec 2002 | 7.67 | 2.21§ | 6.09 |

NOTE: *Crashes and wars that occurred immediately prior to, during, or immediately after a boom. 20th century crashes are documented by Mishkin and White (2002). † Average for 1875-1913; ‡ average for 1867-1913; § average for 1949-2002; ¶ average for 1947-2002.

DEFINITIONS and SOURCES:

Percentage changes (%Δ) are computed as annualized percentage changes in monthly data, i.e., $\%\Delta_t = 1200[(x_t/x_{t-1}) - 1]$ (similar formulas are used for quarterly or annual data). The figures reported in the table are averages of these percentage changes from the month (quarter or year) following the trough month to the peak month, except as noted below.

**Productivity:** For 1879-1946, labor productivity data are from Gordon (2000b). The data are annual; we report the average annual percentage change in productivity from the year after the year in which the trough occurs to the year in which the peak occurs. For 1947-2002, data for non-farm business sector labor productivity (output/hour, seasonally adjusted, 1992=100) are from the Commerce Department. The data are quarterly; we report average annualized growth rates from the quarter following the trough to the quarter of the peak, unless the peak occurred in the first month of a quarter, in which case our averages are based on data through the previous quarter.

**Money stock:** For 1834-1906, data are annual, and we report the average annual percent change in the money stock from the trough year to the peak year. For 1907-2002, data are monthly, and we report the average annualized percent change from the month following the trough to the peak month. The data for 1834-59 are the broad money stock series in Friedman and Schwartz (1970). For 1860-62, we use estimates provided by Hugh Rockhoff. Data for 1863-66 are not available. The data for 1867-1946 are the broad money stock

| Avg. % change bank credit | Avg. % change price level | Avg. % change industrial production | Avg. % change real GDP | Crashes and wars* |
|---|---|---|---|---|
| 13.33 | 13.26 | 11.91 | NA | Crash, May 1835 |
| 7.29 | 7.83 | 11.13 | NA | |
| 5.25 | 6.75 | 7.45 | NA | |
| –2.24 | 25.80 | 9.68 | NA | Civil War |
| 5.26 | –3.54 | 5.93 | NA | |
| 3.20 | –1.22 | 12.76 | 8.40 | Crash, 1880 |
| 10.29 | 4.58 | 11.48 | 6.76 | Crash, summer 1896 |
| 11.64 | 2.33 | 10.04 | 6.58 | Crash, 1900 |
| 7.82 | 1.79 | 12.68 | 7.03 | Crash, Jul-Oct 1903; 1907 |
| 9.41 | 3.27 | 8.98 | 5.90 | |
| 5.02 | 0.02 | 10.95 | 4.33 | Crash, Oct 1929 |
| 5.78 | 1.51 | 19.49 | 10.63 | Crash, Oct 1937–March 1938 |
| 21.42 | 3.42 | –1.01 | 1.67 | World War II; crash, Sep 1946 |
| 5.17 | 3.01 | 10.08 | 6.60 | |
| 3.51 | 0.53 | 2.09 | 2.84 | |
| 4.63 | 1.89 | 6.00 | 4.70 | |
| 8.47 | 1.53 | 7.77 | 5.61 | Crash, Apr-Jun 1962 |
| 9.29 | 3.04 | 2.41 | 3.38 | Crash, Oct 1987 |
| 5.50 | 3.88 | 1.71 | 2.34 | Crash, Aug-Oct 1990 |
| 7.43 | 2.53 | 5.06 | 3.76 | Crash, Aug 2000–Sep 2001 |
| | | | | |
| 4.00 | 0.51 | 6.93 | NA | |
| 6.64 | –1.06 | 5.41 | 4.02† | |
| 1.81 | –0.67 | 12.73 | 2.29 | |
| 7.24 | 4.05 | 3.62 | 3.37¶ | |

DEFINITIONS and SOURCES cont'd:

series in Friedman and Schwartz (1963a). The data for 1947-58 are a broad money stock series from the National Bureau of Economic Research Macro-History Database (series m14195b). For 1960-2002, we use the M2 money stock (seasonally adjusted) from the Board of Governors of the Federal Reserve System.

**Bank credit:** For 1834-1946, data are annual (June figures), and we report the average annual percent change in total bank credit from the trough year to the peak year from *Historical Statistics of the United States* (1976, series X580). Data prior to 1896 are incomplete. For 1947-2002, data are monthly from the Board of Governors of the Federal Reserve System.

**Price level:** For 1834-1912, monthly wholesale price index data (Warren-Pearson and Bureau of Labor Statistics) are from Cole (1938) and the National Bureau of Economic Research Macro-History database (series m04048a/b). For 1913-2002, we use CPI-U (all items, seasonally adjusted).

**Industrial Production:** For 1834-95, data are from Davis (2002). Davis's data are annual; we report the average annual growth rate from the year following the trough (except that for the boom beginning in January 1843, we include 1843) through the peak year. For 1896-1940, (monthly) data are from Miron and Romer (1989). For 1941-2002, we use the Federal Reserve monthly Index of Industrial Production (seasonally adjusted).

**GDP:** For 1879-1946, (quarterly) data are from Balke and Gordon (1986). For 1949-2002, we use real GDP (chained $1996) (quarterly data). We report the average annual growth rate from the quarter following the trough to the peak quarter.

(2002) index of industrial production shows an increase of about 12 percent between 1834 and 1835 (Table 2). Hence, the boom episode coincided with both a general price inflation and rapid real economic growth.

The boom was short-lived. Stock prices peaked in May 1835, and land sales peaked in the first six months of 1836. Monetary policy actions appear to explain the end of the boom and a subsequent banking panic in 1837. Acting under the Deposit Act of June 1836, the Secretary of the Treasury ordered a redistribution of public balances from New York City banks to banks in other states. Subsequently, President Andrew Jackson issued an executive order, known as the Specie Circular, mandating the use of specie (gold and silver) rather than bank notes in the purchase of federal land. In the absence of a well-functioning interregional reserves market, the ensuing outflow of reserves left the New York money market vulnerable to shocks and, according to Rousseau (2002), precipitated the Panic of 1837.[13]

Limited data make it impossible to determine whether the stock market and land booms of the 1830s were justified by reasonable expectations of profit growth. The success of New York's Erie Canal, which was completed in 1825, brought heavy investment in other canal projects. Railroad building took off about the same time. The prospect of greatly reduced transportation costs, combined with rising export prices (chiefly cotton), were real phenomena that could cause equity prices and public land sales to increase. Nevertheless, monetary shocks, and perhaps a dose of irrational exuberance, may have also contributed to the boom, and the end of the boom was caused by monetary policy actions.

**The 1840s.** The stock market recovered quickly from a trough in 1843. Much of the 1843-45 boom was a recovery to a prior (local) peak (see Table 1). Smith and Cole (1935, p. 136) attribute the recovery to "cheap money" and rapid expansion of economic activity, with capital inflows from abroad sustaining the boom (p. 111). As in the 1830s, the stock market boom coincided with a sharp increase in public land sales. The period also was marked by rapid growth of the money stock, price level, and industrial production (see Table 2).

After a pause in the mid-1840s, stock prices increased sharply in 1847 but fell back quickly during the Panic of 1847. Stock prices began to rise again in 1848 and rose at about a 10 percent annual rate through 1852. As during the prior boom, the period 1848-52 was characterized by above average growth of the money stock, price level, and industrial production. Thus, all three of the antebellum stock market booms we identify occurred during periods of rapid growth of the money stock and price level as well as strong economic activity.

## *The Civil War Boom*

Equity prices rose sharply from July 1861 to March 1864, though the real, inflation-adjusted returns to investors were more modest. The stock price index rose at an average annual rate of 40.2 percent during the boom, whereas the price level rose at an average annual rate of 25.8 percent (Table 2). Adjusted for inflation, the market peak occurred in October 1863, and the real stock price index declined precipitously until early 1865, as shown in Figure 6.

It was once thought that the Civil War had encouraged the development of manufacturing and thereby increased the subsequent growth rate of the U.S. economy. Industrial production rose fairly rapidly during the war (see Table 2). Estimates of the economic cost of the Civil War and its impact on growth indicate, however, that although specific firms and industries experienced high profits during the war, the economy as a whole suffered and the war did not increase growth (Goldin and Lewis, 1975). Recent studies have related break points in various asset-price time series to war news, with major Union victories producing increases in asset prices (e.g., McCandless, 1996).

## *From the Civil War to World War I*

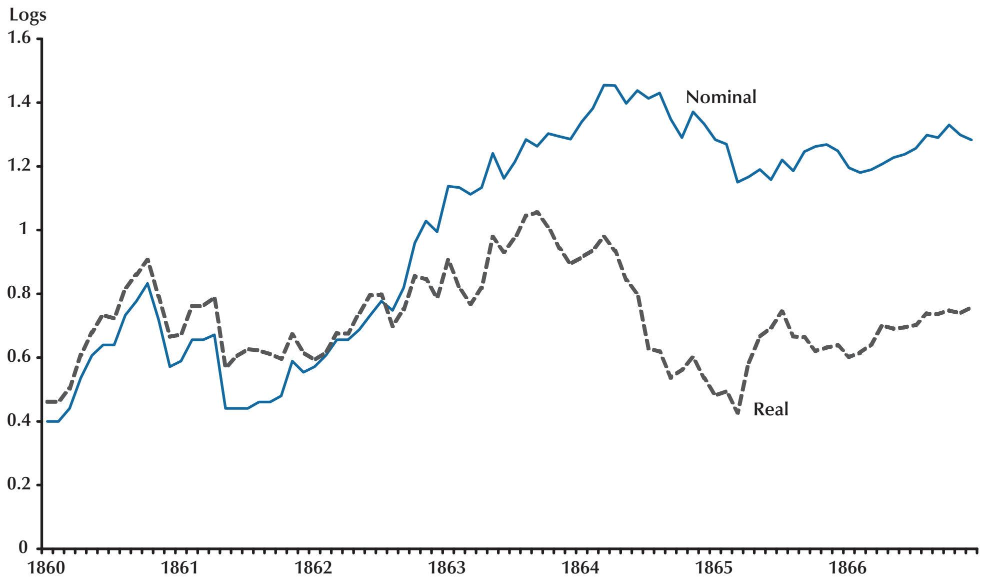
The United States experienced a great industrial expansion during the late 19th and early 20th centuries, with many new corporations formed and listed on the stock exchanges. Our stock market index shows a sustained, though not especially rapid, rise from April 1867 to April 1872, a more rapid rise from June 1877 to June 1881, and a long rise (with two significant interruptions) from August 1896 to September 1906.

The U.S. price level declined almost continuously from 1866 to 1896, with the cost of living falling at an average annual rate of 2 percent (David and Solar, 1977). Figure 7A plots our stock market index alongside a commodity price index for 1866-1913. Like

[13] Temin (1969), by contrast, argues that the U.S. money market tightened when the Bank of England raised its discount rate (i.e., bank rate) to discourage capital outflows from the United Kingdom.

**Figure 6**

**Real and Nominal Stock Price Indices, 1860-66**




the cost of living, commodity prices fell almost continuously until 1896, except from mid-1879 to mid-1882, when commodity prices rose at an average annual rate of 9 percent. At the ends of the stock market booms of 1867-72 and 1877-81, the level of commodity prices was below where it had been at the start of each boom.

By contrast, the price level rose during the booms of 1896-1906. Commodity prices rose at a fairly rapid 4.58 percent annual rate during the 1896-99 boom and again rose during the subsequent booms of 1900-02 and 1903-06 (see Table 2). Hence, the evidence from the post-Civil War era indicates that stock market booms can occur during periods of inflation, deflation, and a fairly stable price level.

Figure 7B plots end-of-quarter values of the stock market index alongside Balke-Gordon's (1986) quarterly estimates of real gross national product (GNP) from 1875 to 1913.[14] Real output growth accelerated in 1879, after several years of modest growth following a cycle peak in October 1873, and achieved an astounding 8.4 percent average rate during the boom of 1877-81 (see Table 2). The growth rates of the stock price index and of both real GNP and industrial production were closely correlated during 1890-1913 (see Table 2). Hence, as in the antebellum era, our evidence indicates that late 19th century stock market booms occurred during periods of unusually rapid growth in real economic activity.

Linking stock market booms to productivity growth during this era is more difficult because productivity data are limited. Figure 7C plots annual estimates of labor productivity growth from 1875 to 1913 alongside June values of our stock price index. In 1896, productivity growth appears to have increased before the stock market did, and the ups and downs in the market that follow are correlated positively with changes in productivity growth.[15]

Next we examine growth of the money and credit stocks. We plot end-of-quarter values of our stock market index and a broad money stock measure ("M2") for 1875-1913 in Figure 7D (M2 data are from Balke and Gordon, 1986). Like real output and commodity prices, M2 grew rapidly during the course of the 1877-81 stock market boom. M2 also grew at double-digit rates during the stock market booms of 1896-99, 1900-02, and 1903-06.

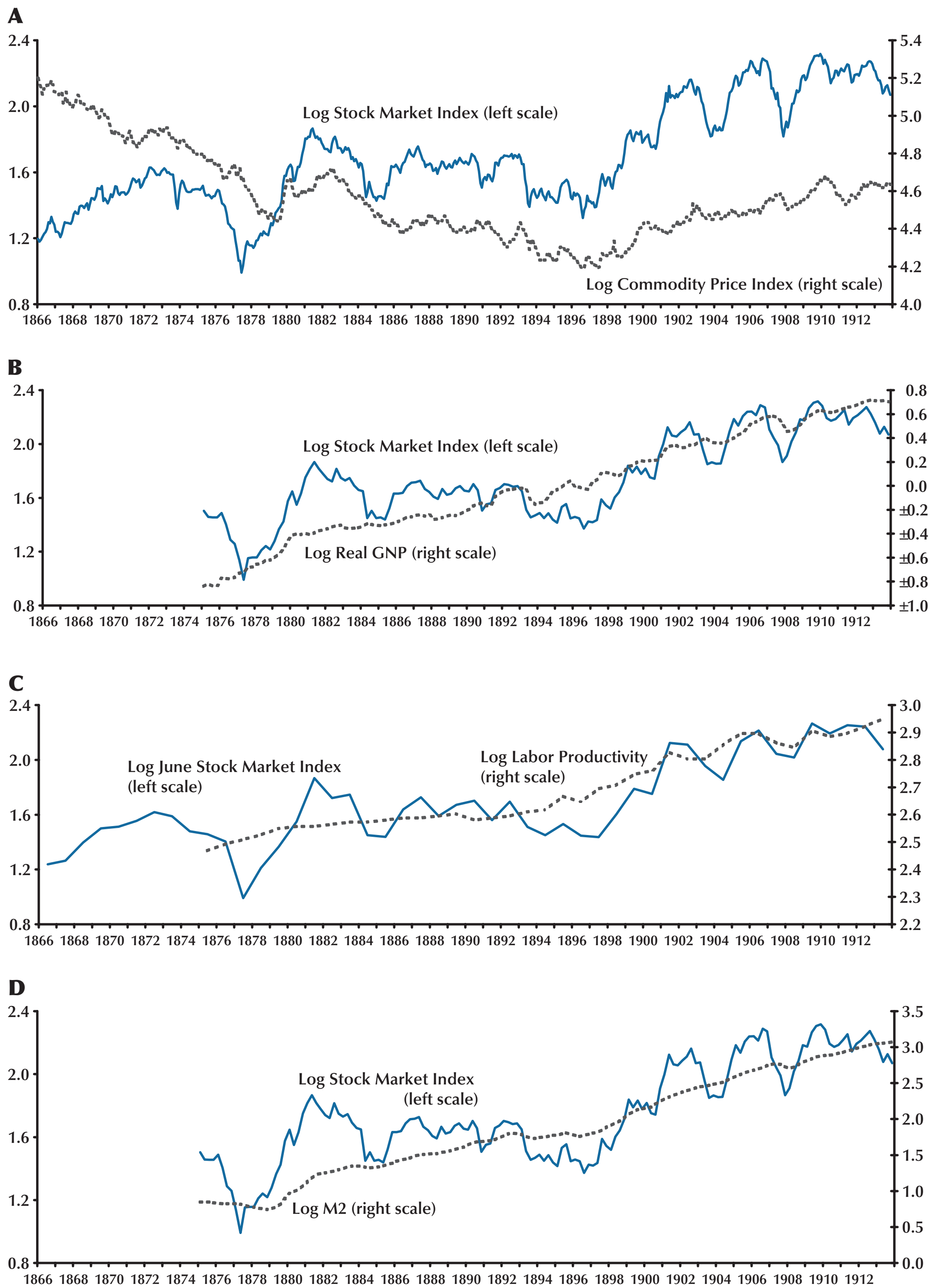
The relationship between the stock market and bank credit is more difficult to ascertain because the only comprehensive credit data for this period are annual. Figure 8A plots total bank credit alongside June values of the stock market index for 1866-1913, and Figure 8B plots annual data on the stock

[14] Estimates for years before 1875 are not available.

[15] The pattern of growth in total factor productivity is similar to that of labor productivity in this period.

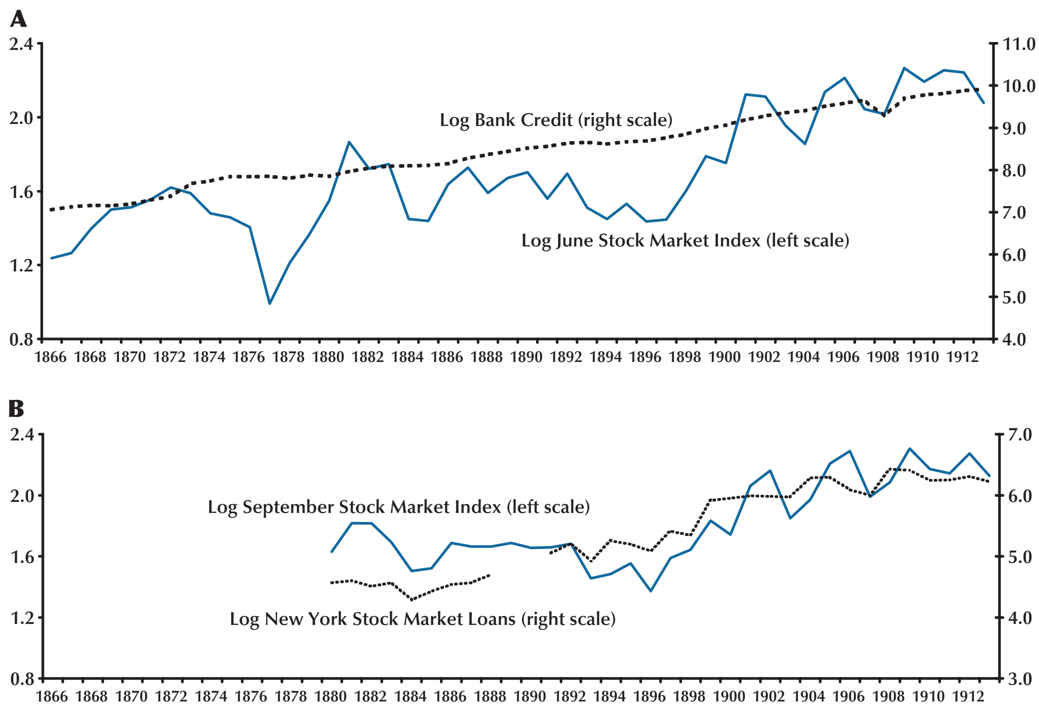
## Figure 7

**Stock Market Index and Macroeconomic Data, 1866-1913**



## Figure 8

**Stock Market Index, Bank Credit, and New York Stock Market Loans, 1866-1913**




market loans of New York City national banks alongside the stock market index for 1880-1913. Whereas the correlation between the growth of total bank credit and the stock market index is low, Figure 8B indicates that stock market loan growth increased during the booms of 1896-99, 1900-02, and 1903-06, as well as during the recovery of 1908-09.[16]

Railroads were the most visible industry in the economic expansion and stock market between 1867 and 1873. Railroad investment hit a peak in 1871-72, as did stock prices (Fels, 1959, p. 98). The collapse of Jay Cooke and Company, the principal financier of the Northern Pacific Railroad, triggered the financial crisis of 1873. Railroad building was stagnant until 1876, but began to expand rapidly in 1877, and the stock market revived. Although the railroads grew faster than any other industry, the 1870s and early 1880s also witnessed rapid growth in manufacturing, as well as agricultural output and productivity (Friedman and Schwartz, 1963a, pp. 35).

On the monetary side, in 1879 the United States returned to the gold standard, which had been suspended during the Civil War. Hence, the stock market boom occurred in an environment of strong growth of real economic activity and successful resumption of the international monetary standard. While there were reasons to be optimistic about the growth of corporate earnings in this environment, contemporary accounts, cited by Fels (1959, pp. 120-25), suggest that risk premiums fell unjustifiably and investors were swept up in a "bubble of overoptimism."

Similar contemporary and historical accounts cite "speculative activity" as one reason for rapid increases in equity prices during subsequent booms. For example, Friedman and Schwartz (1963a, p. 153) write that "The years from 1902 to 1907 were characterized by industrial growth…by speculative activity in the stock market, and by a wave of immigration."

In summary, we find that the 19th and early

[16] Data on stock market loans are as of call report dates (usually September) from Bordo, Rappaport, and Schwartz (1992). Although stock market loans appear to rise and peak before the stock market, because the data on loans and the stock market index are not for the same month in each year, we are hesitant to draw any conclusions about timing.

20th century booms occurred when growth of real output and the money stock were high, but we observe no consistent pattern with respect to the price level, i.e., booms occurred during periods of deflation, inflation, and more-or-less stable prices. Anecdotes suggest that speculation also characterized most booms, but a quantitative assessment of the extent to which the rise in stock prices during booms exceeded rational pricing based on fundamentals is beyond the scope of this article.

## *20th Century Booms*

The period between the Panic of 1907 and the beginning of the bull market of the 1920s was characterized by a choppy market. A significant panic occurred at the start of World War I in 1914, and the U.S. stock market was closed for four months. There were no sustained movements in the market between 1914 and 1923.

**1923-29.** In terms of duration and amplitude, the U.S. stock market boom of 1994-2000 has but one historical rival—the boom of 1923-29. The market index rose at an annual average rate of about 20 percent during both six-year booms. Both periods were also characterized by low and stable inflation and high average growth of real GNP and industrial production. Productivity growth also increased during both the 1920s and 1990s. In the 1920s, however, the increase in productivity growth occurred in the three years preceding the stock market boom, and productivity growth slowed during the boom period. By contrast, in the 1990s, productivity began to accelerate around 1995, and rapid productivity growth coincided with the stock market boom.

Figure 9A plots our stock market index alongside the CPI for 1915-40. A rapid increase in the price level during World War I was followed by deflation in 1920-21. The consumer price level was virtually unchanged over the remainder of the 1920s. As illustrated in Figure 9B, real GNP exhibited positive growth during 1923-29, interrupted by brief recessions in 1923-24 and 1927. GNP growth during the boom averaged above the historical norm, but not above the growth rates experienced during prior booms (see Table 2). Industrial production also grew rapidly during the 1923-29 boom, shown in Figure 9C, and reached a peak a few months before the stock market peak in September 1929. Average growth of industrial production during the boom was similar to that experienced in late 19th century booms (Table 2).

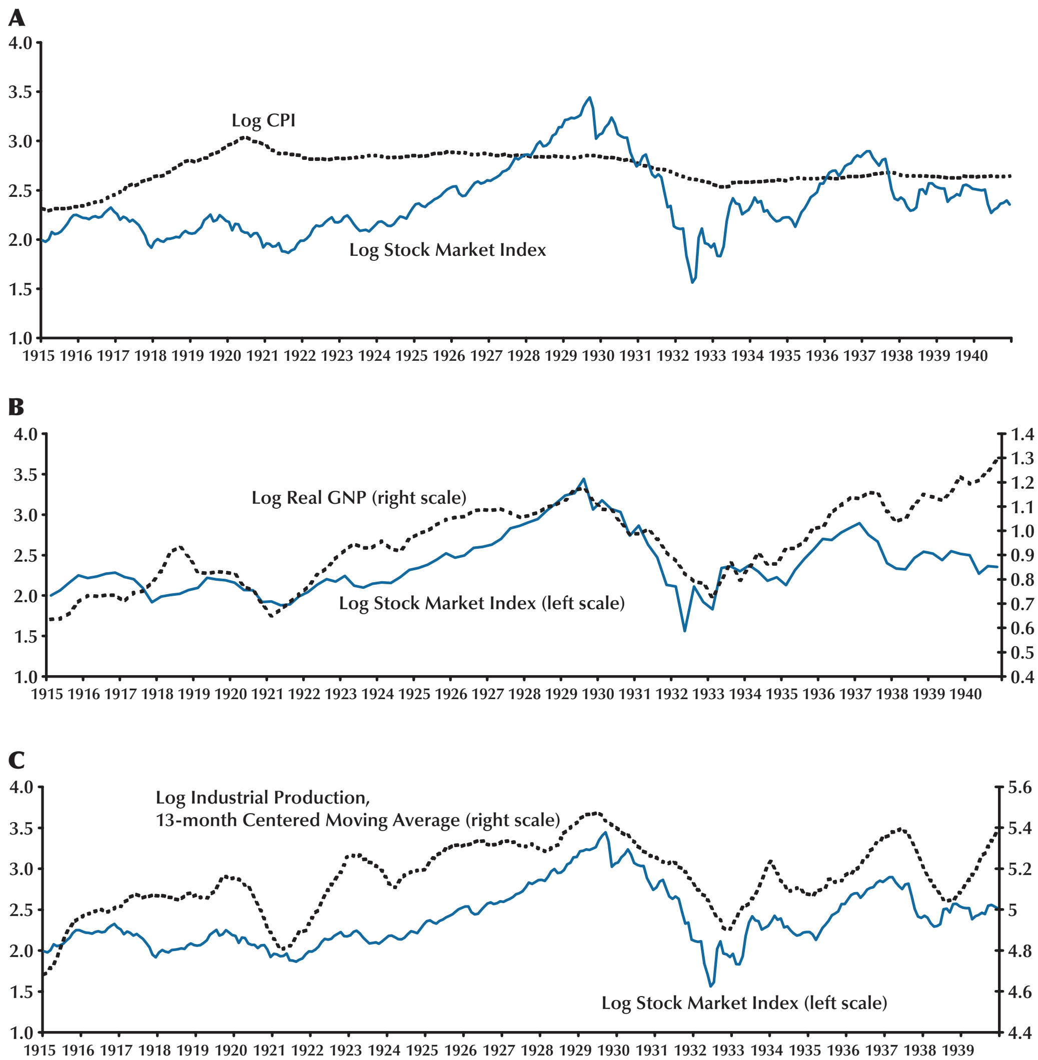
Figure 10 plots annual estimates of nonfarm labor and total factor productivity for the U.S. economy, from Kendrick (1961), alongside June values of our stock market index for 1889-1940. Both labor and total factor productivity grew relatively rapidly in the early 1920s. Economists have attributed this growth to the diffusion of technological breakthroughs that had occurred in the late 19th and early 20th centuries, including the internal combustion engine and inventions that made the industrial use of electric power practical. Although the stock market boom of the 1920s did not coincide precisely with the productivity acceleration, as it did during 1994-2000, both booms have been associated with technological breakthroughs that revolutionized production in numerous existing industries as well as created entirely new industries. The high-flying stocks of the 1920s, such as RCA, Aluminum Company of America, United Aircraft and Transportation Corporation, and General Motors were direct beneficiaries of the new general-purpose technologies and were expected to have high profit potential, not unlike the "dot-com" stocks that led the boom of the 1990s.[17]

Whereas technological progress and accelerating productivity would be expected to generate an increase in the growth of corporate profits, and thereby justify an increase in stock prices, the question remains whether such "fundamentals" can explain the entire increase in the market. Contemporary observers disagreed about whether the stock market boom of 1923-29 was justified by realistic expectations of future earnings, as do economists who look back at the episode. Yale economist Irving Fisher famously defended the level of the stock market. For example, he argued that the increase in corporate profits during the first nine months of 1929 "is eloquent justification of a height-

[17] The internal combustion engine and electric motors are often referred to as general-purpose technologies because of their wide applicability and potential to increase productivity in many industries. The microprocessor is also regarded as a general-purpose technology, and the increase in productivity growth that occurred around 1995 is commonly attributed to the widespread application of computer technology. Greenspan (2000), for example, contends that "When historians look back at the latter half of the 1990s a decade or two hence, I suspect that they will conclude we are now living through a pivotal period in American economic history. New technologies that evolved from the cumulative innovations of the past half-century have now begun to bring about dramatic changes in the way goods and services are produced and in the way they are distributed to final users. Those innovations, exemplified most recently by the multiplying uses of the Internet, have brought on a flood of startup firms, many of which claim to offer the chance to revolutionize and dominate large shares of the nation's production and distribution system." See also David (1990), David and Wright (1999), Gordon (2000a), and Jovanovic and Rousseau (2004).

**Figure 9**

**Stock Market Index and Macroeconomic Data, 1915-40**




ened level of common stock prices" (quoted in White, 2004, p. 10). There were naysayers, however, including Paul M. Warburg, a leading banker and former member of the Federal Reserve Board. Warburg argued in March 1929 that the market reflected "unrestrained speculation" that, if continued, would result in a collapse and a "general depression involving the entire country."[18]

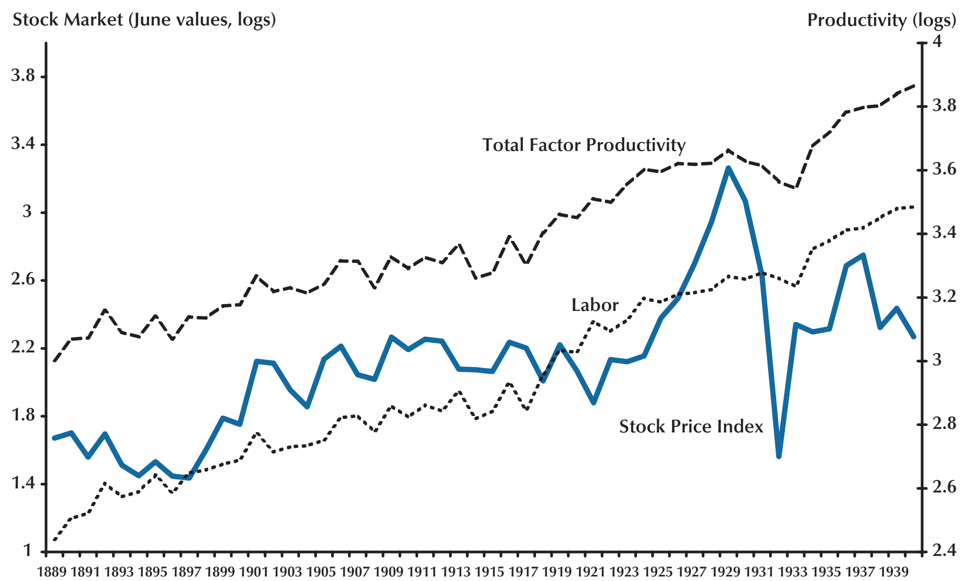
In addition to rapid earnings growth, Fisher (1930) cited improved management methods, a decline in labor disputes, and high levels of investment in research and development as reasons why stocks were not overvalued in 1929. McGrattan and Prescott (2003) argue that Fisher was correct. Although the total market value of U.S. corporations in 1929 exceeded the value of their tangible capital stock by 30 percent, McGrattan and Prescott (2003) estimate that the value of intangible corporate assets, e.g., the value of R&D investment, fully justified the level of equity prices.

Other researchers have examined the growth of corporate earnings and dividends during the 1920s, and most conclude that equity prices rose far higher than could be justified by reasonable

[18] Quoted in Galbraith (1961, p. 77).

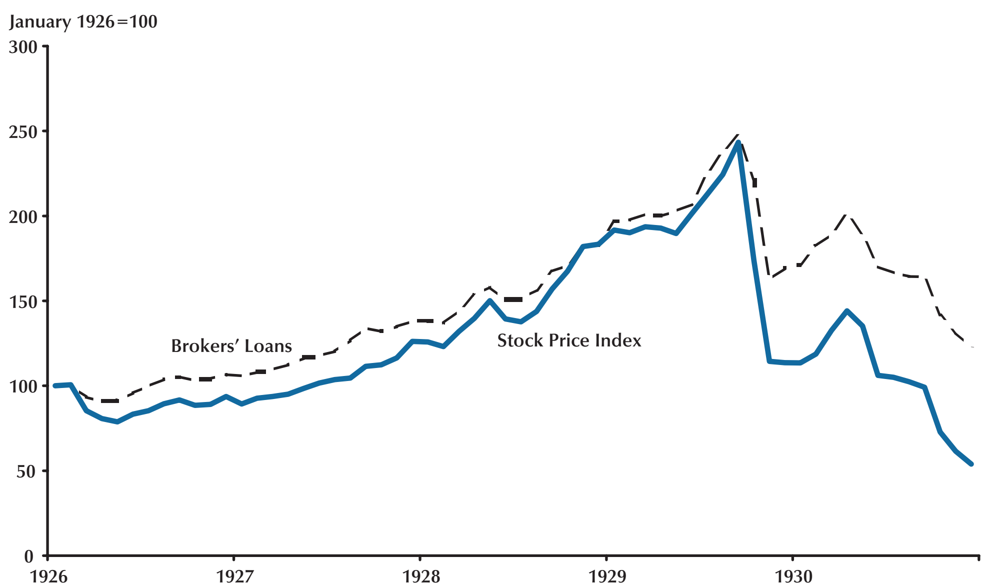
## Figure 10

### Productivity and Stock Price Index, 1889-1940




## Figure 11

### Stock Price Index and Brokers' Loans, 1926-30



expectations of future dividends. White (2004), who surveys and extends this literature, concludes that the increase in stock prices during 1928-29 exceeded what could be explained by earnings growth, the earnings payout rate, the level of interest rates, or changes in the equity premium, all of which are components of a standard equity pricing model.

Several Federal Reserve officials, Secretary of Commerce Herbert Hoover, and a number of other prominent public officials attributed the stock market boom to loose monetary policy and the rapid growth of credit. Neither the money stock nor total bank credit grew at an unusually fast pace during 1923-29 (see Table 2). Brokers' loans rose rapidly and in line with stock prices, however, as Figure 11 illustrates. Federal Reserve officials viewed the growth in loans to stock brokers and dealers with alarm. Many adhered to the so-called Real Bills Doctrine, which focuses on the composition, rather than total quantity, of bank credit. According to this view, banks should make only short-term commercial and agricultural loans to finance the production of real goods and services because loans to finance purchases of financial assets tend to promote speculation, misallocation of economic resources, and inflation.[19] Moreover, asset price bubbles inevitably lead to crashes and depressions, which are required to "purge the rottenness out of the system," as U.S. Treasury Secretary Andrew Mellon famously once said (Hoover, 1952, p. 30).

Federal Reserve officials debated whether their actions had contributed to the growth of brokers' loans and financial speculation. Some officials complained that the Fed was fueling the stock market boom by making discount window loans to banks that in turn lent to stock brokers and dealers. Although only short-term commercial and agricultural loans could be used as collateral for discount window loans, some Federal Reserve Board members argued that banks should be forced to liquidate their loans to stock brokers and dealers before being allowed to borrow at the discount window with eligible collateral. In February 1929, the Federal Reserve Board directed the Reserve Banks to ensure that Federal Reserve credit was not used to finance speculative activity: "The Board…has a grave responsibility whenever there is evidence that member banks are maintaining speculative security loans with the aid of Federal Reserve credit. When such is the case the Federal Reserve Bank becomes either a contributing or a sustaining factor in the current volume of speculative security credit. This is not in harmony with the intent of the Federal Reserve Act nor is it conducive to the wholesome operation of the banking and credit system of the country."[20]

Open market operations constituted a second channel by which Federal Reserve credit contributed to the stock market boom, according to critics. Open market purchases made during economic recessions in 1924 and 1927 came when "business could not use, and was not asking for increased money," Federal Reserve Board member Adolph Miller alleged.[21] In the absence of increased demand for Fed credit for "legitimate" business needs, according to this view, open market purchases increased the supply of funds available to purchase stocks and thereby inflated the bubble.

Fed officials were not unanimous in their views. In general, Federal Reserve Bank officials disagreed with the idea that it was desirable, or even possible, to control commercial banks' use of funds obtained from the discount window. Reserve Bank officials tended to argue for discount rate increases, rather than any form of "direct pressure," to curtail discount window borrowing.

Fed officials also disagreed about the relationship between open market operations and the stock market. Disagreement centered on whether the large open market purchases of 1924 and 1927 had been desirable or harmful. Benjamin Strong, the governor of the Federal Reserve Bank of New York from its inception in 1914, was the Fed's dominant figure and head of the System's Open Market Investment Committee until his death in 1928. Although other System officials acquiesced, the open market purchases of 1924 and 1927 were largely Strong's idea.[22] When asked by the Senate Banking Com-

[19] Contemporaries argued that banks "pushed" loans to purchase stocks on an unsophisticated public. Rappoport and White (1994) show, however, that the risk premium on brokers' loans increased sharply in the late 1920s, indicating that the growth of brokers' loan volume reflected growing demand rather than increasing loan supply.

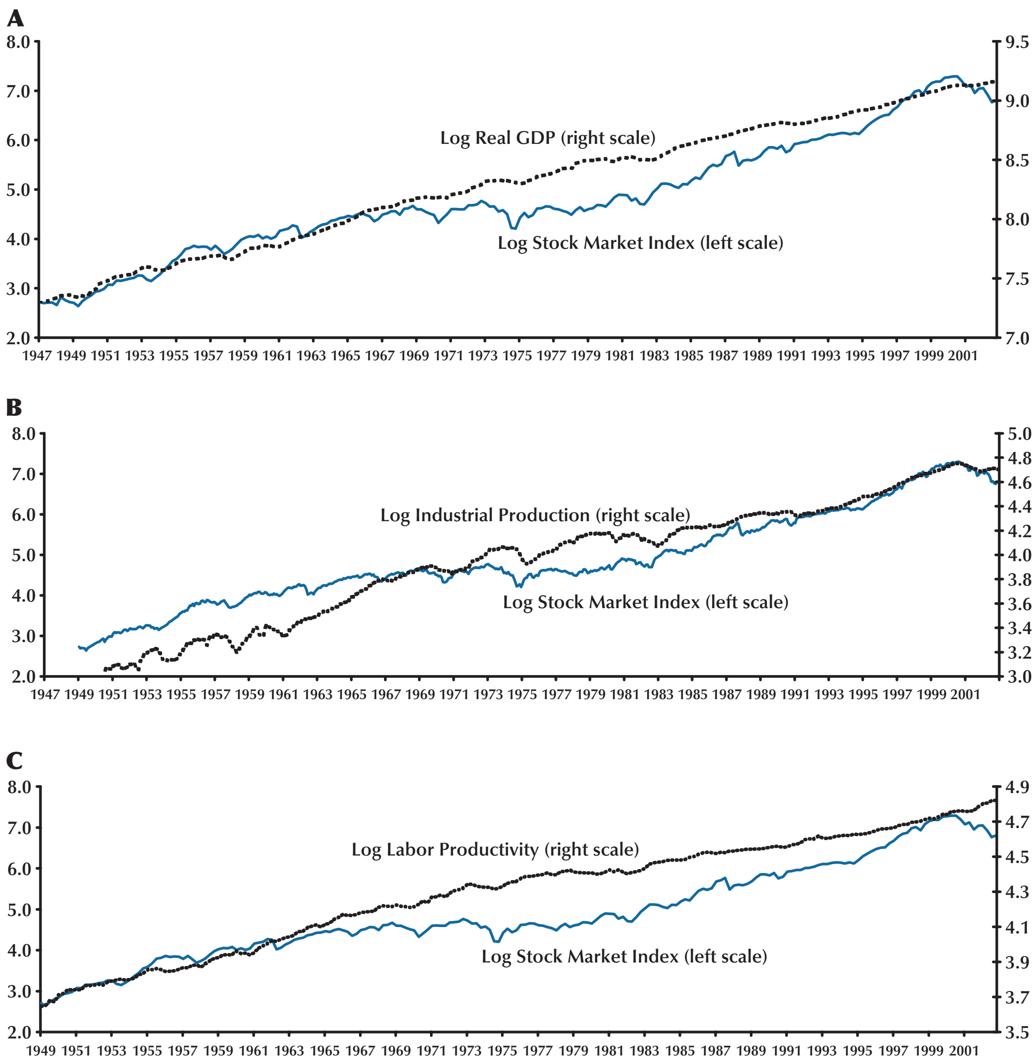
[20] Quoted in Chandler (1971, pp. 56-57).

[21] Testifying before the Senate Banking Committee in 1931 (quoted in Wheelock, 1991, pp. 98-99).

[22] Strong's motives for engaging in open market purchases in 1924 and 1927 have been debated. Meltzer (2002, pp. 197-221) finds that the actions were undertaken both to encourage domestic economic recovery from recessions and to assist the Bank of England in attracting and maintaining gold reserves by lowering U.S. interest rates relative to those in the United Kingdom. Meltzer concludes, however, that international cooperation was relatively more important than domestic recovery in 1927. Wheelock (1991) reports empirical evidence that both domestic and international goals were important throughout 1924-29.

## Figure 12

**Stock Market Index and Macroeconomic Data (1), 1947-2002**



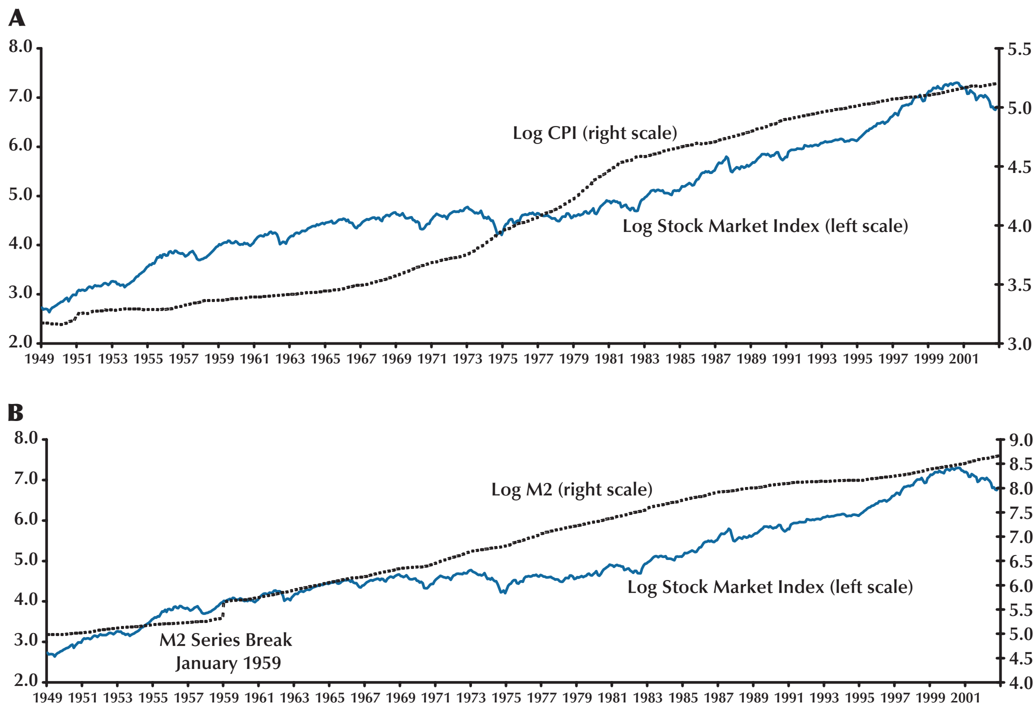

mittee in 1931 whether those purchases had been appropriate, some Federal Reserve Bank officials argued that they had been useful but perhaps too large, while other Fed officials contended that no open market purchases should have been made in those years. For example, officials of the Federal Reserve Bank of Chicago argued that the purchases in 1924 had been too large and "in 1927 the danger of putting money into the market was greater than in 1924 as speculation was well under way." Officials of the Federal Reserve Bank of Richmond went further, arguing that "we think…securities should not have been purchased in these periods, and the aim should have been to decrease rather than augment the total supply of Federal Reserve Credit."[23] Although not reflected in growth of the money stock or total bank credit, critics charged that the Fed had pursued a dangerously loose monetary policy as reflected in the growth of brokers' loans and the rise in the stock market.

**The 1930s.** At its nadir in June 1932, the S&P stock market index stood at just 15 percent of its September 1929 peak. The market staged a brief recovery in 1933, then surged from March 1935 to February 1937. The boom of 1935-37 coincided with a period of rapid growth in real output and the

[23] These quotes are from Wheelock (1991, p. 100).

**Figure 13**

**Stock Market Index and Macroeconomic Data (2), 1947-2002**




money stock and came in the middle of a decade of unusually rapid growth in total factor productivity (Field, 2003). Inflation, however, remained low (see Table 2). The adoption of highly restrictive monetary and fiscal policies in 1936-37 snuffed out the economic recovery and brought a halt to the stock market boom in early 1937.

**World War II.** The next stock market boom occurred during World War II. U.S. equity prices declined when the war began in Europe, hitting a low point in March 1942. The stock market then rose as the U.S. economy was being mobilized for war. Similar to the view that the Civil War had a positive effect on postwar economic growth by hastening the development of manufacturing industries, World War II has also been viewed as an important source of technological progress and postwar economic growth. Field (2003) shows, however, that most of the seeds of postwar growth were sown during the 1930s and that productivity growth was slow during the war outside the munitions industries. Thus, the stock market boom probably reflected more the rapid increases in output and liquidity during the war as the economy finally reached full employment than productivity-driven expectations of a long-run increase in the growth of corporate profits.

## *The Post-World War II Era*

The nearly 60 years since the end of World War II can be divided into three distinct eras. The first, from the end of the war to the early 1970s, was characterized by a rising stock market, strong real economic growth, a high average rate of productivity growth, and (toward the end of the period) rising inflation. The second era, covering the 1970s and early 1980s, was characterized by stagflation—high inflation coupled with both highly variable and low average output and productivity growth. Nominal stock returns were flat, and ex post real returns were negative. In the third era, from the mid-1980s to the present, real output growth has been more stable and, on average, higher than it was before 1980. Inflation has fallen markedly, and, since the mid-1990s, productivity growth has returned to the high average rates observed in the 1950s and early 1960s. Stock returns have been high, both in nominal and real terms, especially during the booms of 1984-87 and 1994-2000. Figures 12 (panels A through C) and 13 (panels A and B) illustrate these patterns.

Technological breakthroughs in chemicals, electronics, and other industries during the 1930s and 1940s enabled rapid growth in labor productivity and living standards during the 1950s and 1960s (Field, 2003; Gordon, 2000a). These decades also witnessed high levels of investment in public infrastructure and education. Our metric identifies three specific stock market booms in these decades, though one might characterize the entire period as a boom.

The first boom began as the economy pulled out of a mild recession in 1949. The market rose at an average annual rate of 18 percent between June 1949 and January 1953. Following a pause during another recession in 1953-54, the market rose at an average annual rate of nearly 27 percent from September 1953 to July 1956. Although the growth rates of output and productivity were somewhat slower during the latter boom, the return to more stable monetary and fiscal policies after the Korean War may explain why the stock market increased at a faster pace. The third distinct boom lasted from June 1962 to January 1966 and coincided with a long period of economic expansion, characterized by high average growth of GDP, industrial production, and productivity, as well as low inflation.

The stock market performed poorly during the 1970s, with the market peak of January 1973 not reached again until July 1980. No stock market booms occurred during this decade of adverse supply shocks, low productivity growth, highly variable output growth, and high inflation. The next market boom occurred during the three-year period from July 1984 to August 1987. This period of economic recovery was characterized by moderately strong real economic growth and falling inflation, but productivity growth that was below its post-World War II average.

The macroeconomic environment of the April 1994–August 2000 boom period is well known. This period was characterized by somewhat above-average growth of real output and industrial production and low and stable inflation. An increase in the trend growth rate of productivity to approximately the rate that had prevailed during the 1950s and 1960s was the feature of this boom period that has received the most attention; it has often been cited as the main fundamental cause of the stock market boom.

## CONCLUSION

Our survey finds that U.S. stock market booms have occurred in a variety of macroeconomic environments. Nevertheless, some common patterns are evident:

1. Most booms occurred during periods of relatively rapid economic growth and, to the extent it can be measured, increases in productivity growth. This suggests that booms were driven at least to some extent by fundamentals.
2. Many booms also occurred during periods of relatively rapid growth of the money stock and bank credit, reflecting either passive accommodation of booms by the banking system or expansion of the monetary base by means of gold inflows or monetary policy actions.
3. Stock market booms have occurred in periods of deflation (e.g., the late 1870s and early 1880s), in periods of inflation (e.g., the 1830s, 1840s, late 1890s, and early 1900s) and in periods of price stability (e.g., the 1920s and 1990s). In general, booms appear to have been driven by increases in the growth of real output and productivity and can persist despite either inflation or deflation so long as the growth of output and productivity remains strong.[24] The tendency for the money stock, but not the price level, to grow rapidly during booms suggests that money growth accommodated increases in productivity, which fueled booms. In the absence of an increase in money growth, the quantity theory predicts that an increase in productivity and potential output growth would lead to deflation. In future work, we intend to examine formally whether accelerations in money stock growth during booms were quantitatively consistent with increases in long-run productivity growth.
4. Wartime experience seems to have been different from peacetime, but no consistent

[24] Periods of depressed stock market returns occurred during periods of declining productivity growth or other adverse supply shocks. Some such periods were characterized by deflation (e.g., 1929-32), while others were characterized by inflation (e.g., the 1970s). In deflationary periods when aggregate supply growth outpaced aggregate demand, such as in the late 1870s and early 1880s, the market did as well as it did in the inflationary 1830s, 1840s, late 1890s, and early 1900s, when rapid aggregate supply growth was surpassed by demand growth (Bordo, Lane, and Redish, 2004; Bordo and Redish, 2004). This contrasts sharply with the experiences of the Great Depression, when collapsing aggregate demand coincided with a decline in aggregate supply, and the Stagflation of the 1970s, which was characterized by excessive growth of aggregate demand in the face of low or negative aggregate supply growth.

wartime pattern emerges. The old adage that "war is good for the market" does not seem to always hold up. Stock market booms occurred during World War II and to a lesser extent the Civil War, but market performance was relatively poor during World War I and the Vietnam War.

The stock market booms of 1923-29 and 1994-2000 stand alone in terms of their length and the extent to which market averages increased. Both bull markets have been attributed to increased productivity growth associated with the widespread application of new general-purpose technologies that promised new eras of rapid economic growth. The macroeconomic environments in which these two booms occurred were strikingly similar. Both decades saw above-average, though not exceptional, growth of real output and industrial production, while consumer price inflation was quite low and stable. Productivity growth did increase in both the 1920s and 1990s; though, in the 1920s, productivity growth appears to have occurred prior to the stock market boom, whereas the increase in productivity growth during the 1990s coincided with the boom.

Policymakers paid a great deal of attention to the stock market during each of the great booms. In the 1920s, debate centered on whether the Fed had fostered the boom by oversupplying Federal Reserve credit through open market purchases and inadequate administration of the discount window. Many Fed officials adhered to the Real Bills Doctrine, which held that an increase in credit beyond that required to finance short-term production and distribution of real goods would end up fostering speculation and inflation. Despite the absence of consumer price inflation, officials interpreted the stock market boom as evidence of inflation. Accordingly, the Fed tightened policy in 1928 and 1929, which may have hastened the collapse of both stock prices and the economy (Schwartz, 1981; Hamilton, 1987). Lingering doubts about the efficacy of using monetary policy to foster economic recovery then contributed to the Fed's failure to ease aggressively to fight the Great Depression (Wheelock, 1991; Meltzer, 2002).

The Fed's understanding of the role of monetary policy was quite different in the 1990s and 2000s. Transcripts of FOMC meetings indicate that, during the 1990s, the Fed was mainly concerned about the potential consequences of a sharp decline in stock prices, fearing that falling stock prices would reduce consumption by reducing wealth. Although the Fed did tighten policy in the later stages of the boom by raising its target for the federal funds rate in 1999-2000, it eased aggressively when stock prices declined and the economy entered recession. In sharp contrast to its policy in the early 1930s, the Fed maintained an aggressively accommodative monetary policy well after the stock market decline had ended, with the objectives of preventing deflation and encouraging economic recovery.

Our survey of U.S. stock market booms finds that booms do not occur in the absence of increases in real economic growth and perhaps productivity growth. We find little indication that booms were caused by excessive growth of money or credit, though 19th century booms tended to occur during periods of monetary expansion. The view that monetary authorities can cause asset market speculation by failing to control the use of credit has been largely discarded. Nevertheless, anecdotal evidence suggests that the stock market sometimes rises more than can be justified by fundamentals, though economists continue to debate whether even the market peak of 1929 was too high. Not surprisingly, these questions leave unsettled the issue of how monetary policy should respond to an asset price boom. Although one can offer plausible theoretical arguments for responding proactively to an asset price boom, our survey suggests that policymakers should be cautious about attempting to deflate asset prices without strong evidence that a collapse of asset prices would have severe macroeconomic costs.

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# What Does the Federal Reserve's Economic Value Model Tell Us About Interest Rate Risk at U.S. Community Banks?

Gregory E. Sierra and Timothy J. Yeager

Interest rate risk at commercial banks is the risk that changes in interest rates will adversely affect income or capital. Such risk is an inherent part of banking because banks typically originate loans with longer maturities than the deposits they accept. This maturity mismatch between loans and deposits causes the net interest margin (NIM)—the spread between loan rates and deposit rates—to fall when interest rates rise, because interest rates on deposits adjust more quickly than interest rates on loans. Further, when interest rates rise, the economic value of longer-term instruments (assets) falls by more than the economic value of shorter-term instruments (liabilities), thus reducing the bank's capital.

Bankers became increasingly concerned about interest rate risk following the savings and loan (S&L) crisis. In the early 1980s, many thrifts became insolvent after interest rates rose sharply, setting off a crisis that eventually required a $150 billion taxpayer bailout (Curry and Shibut, 2000). Thrifts were particularly vulnerable to interest rate risk because of the large maturity mismatch that resulted from using short-term deposits to fund long-term home loans. Nevertheless, banks devoted considerable resources to measuring and managing their exposure to interest rate risk. Many regional and money-center banks implemented elaborate models to measure their exposure and began to use sophisticated asset and liability management to manage their risk.

Bank supervisors also were challenged to stay abreast of the industry's ability to take on interest rate risk, and they responded with three related initiatives. First, bank examiners received capital markets training to help them understand better the techniques for measuring and managing interest rate risk. Second, bank supervisors explicitly incorporated interest rate risk into their ratings system in 1997, transforming the "CAMEL" rating system into "CAMELS."[1] The "S" rating stands for a bank's sensitivity to market risk, which includes interest rate risk and exposure to trading account assets, exchange rates, and commodity prices.[2] The third supervisory initiative was to develop a measure of interest rate risk that examiners could use to risk-scope a bank—that is, to pinpoint the areas of the bank that warrant closer scrutiny—and to conduct off-site surveillance. Economists at the Board of Governors of the Federal Reserve System developed a proprietary economic value of equity model called the economic value model (EVM), which is a duration-based estimate of interest rate sensitivity for each U.S. commercial bank (Houpt and Embersit, 1991; Wright and Houpt, 1996). The Federal Reserve operationalized the model in the first quarter of 1998 by producing a quarterly report (called the Focus Report) for each bank. The Focus reports are the confidential supervisory reports that provide the detailed output of the Fed's EVM.

The EVM's interest rate sensitivity assessment is most relevant for community banks, which we define as those with less than $1 billion in assets and no interest rate derivatives. Larger banks often

[1] Board of Governors, SR 96-38. CAMEL stands for capital adequacy, asset quality, management, earnings, and liquidity.

[2] For the majority of banks that have no trading accounts or foreign currency exposures, market risk and interest rate risk are equivalent.

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have derivatives or other balance-sheet complexities that the EVM ignores, making the output from the EVM more questionable. The EVM also is more appropriately applied to community banks because community banks are examined less often than larger banks and the EVM is usually the only tool for off-site interest rate risk assessment available to examiners for those banks. Community banks devote fewer resources to modeling and measuring their interest rate risk than do regional and money-center banks, which normally have full-time staff devoted to such tasks. Consequently, examiners of larger institutions usually have access to more sophisticated and often more timely information than that provided by the EVM.

This paper investigates the effectiveness of the EVM by examining whether model estimates are correlated with community bank measures of interest rate sensitivity during recent periods of both rising and falling interest rates. Because the model is relatively new, it has yet to be validated against actual bank performance. The Federal Open Market Committee (FOMC) increased the federal funds rate six times in 1999 and 2000, and then lowered the federal funds rate 12 times in 2001 and 2002. A strong correlation between the EVM's estimate of interest rate sensitivity and measures of interest rate risk during these periods would suggest that the model provides a useful surveillance tool to community bank supervisors.

We find that estimates from the Fed's EVM are correlated with the performance of U.S. community banks in the manner the EVM suggests. Specifically, the banks that the EVM identifies as the most liability sensitive—those most sensitive to rising rates—show the biggest deterioration in performance during the period of rising interest rates between 1998 and 2000. The most liability-sensitive banks also show the greatest improvement in performance measures during the 2000-02 period of falling rates. The evidence indicates, then, that the EVM is a useful tool for supervisors interested in identifying the minority of banks that are highly sensitive to interest rate changes.

## RELATED LITERATURE

Researchers have examined the interest rate sensitivity of depository institutions in some detail. There are two general lines of inquiry. The first line of inquiry asks whether depository institutions are exposed to interest rate changes and, if so, how large is that exposure on average? The motivation for this research often is to assess the impact that monetary policy or unexpected inflation might have on financial intermediation. Most studies measure interest rate sensitivity by regressing the firm's stock return on a market index and an interest rate. Flannery and James (1984), Aharony, Saunders, and Swary (1986), Saunders and Yourougou (1990), Yourougou (1990), and Robinson (1995) find that bank stock prices react to (unexpected) interest rate changes. A major limitation of this research is that the vast majority of U.S. banks are excluded from the analysis because they have no publicly traded equity. Flannery (1981, 1983) constructs a model that estimates the effect of rate changes on a bank's net operating income. The model has the added advantage that it indirectly estimates the maturities of the assets and liabilities. Flannery finds that the impact of rate changes on long-run bank earnings is small, averaging only 5.6 percent of net operating earnings. He also finds that banks are slightly asset sensitive; that is, profits increase with rising interest rates. These results, however, contradict much of the literature—including some of Flannery's later work—which shows that banks tend to be exposed to rising rates.

A second line of inquiry attempts to isolate a bank-specific measure of interest rate risk to separate banks by their interest rate sensitivity. Regulators are interested in this process because bank-specific measures provide opportunities to identify high-risk banks. Flannery and James (1984) construct a one-year gap measure and quantify the correlation between this measure and the portion of a bank's stock return driven by interest rate changes. They find that this simple maturity variable has statistically significant explanatory power. Gilkeson, Hudgins, and Ruff (1997) use output from a regulatory gap model for thrifts between 1984 and 1988. They also find a statistically significant correlation between net interest income and the one-year gap measure. Robinson and Klemme (1996) find that bank holding companies with relatively high levels of mortgage activity have higher degrees of interest rate sensitivity than other bank holding companies, as reflected by changes in stock prices. Finally, Lumpkin and O'Brien (1997) construct a comprehensive measure of thrifts' portfolio revaluations caused by interest rate changes. They fail to find evidence that such revaluations influence stock returns beyond the influence already captured by more general movements in interest rates.

This article adds to the evidence that banks are liability sensitive, though the interest rate sensitivity, on average, is small. Our results are consistent with Gilkeson et al. (1997) and show that even accounting-based measures of interest rate sensitivity can have significant explanatory power to aid bank supervisors in risk-scoping and monitoring the interest rate exposure of commercial banks. Our results imply, as well, that large rate increases are unlikely to have significant adverse effects on the banking industry, which is also consistent with previous literature.

## A MEASURE OF RATE SENSITIVITY: THE EVM

Interest rate risk is the product of a bank's rate sensitivity and subsequent rate changes. If rate changes are unpredictable, then measurement of a bank's rate sensitivity is crucial to monitoring and controlling interest rate risk. Models that measure interest rate sensitivity fall into one of two categories. Earnings-at-risk models estimate changes in a bank's net interest margin or net income in response to changes in interest rates. Equity-at-risk models estimate changes in a bank's market value of equity, or its economic capital, in response to changes in interest rates.

Federal Reserve economists used the concept of duration to develop an equity-at-risk model of a bank's interest rate sensitivity. Duration is the present-value weighted-average time to maturity of a financial instrument.[3] Conceptually, it is the price sensitivity of a financial instrument to a change in interest rates. If, for example, the (modified) duration of a Treasury bond is –3.0, the bond is projected to lose 3 percent of its value, given a 100-basis-point increase in interest rates. The price of a financial instrument with a larger duration will fluctuate more in response to interest rate changes than the price of an instrument with a smaller duration.

To ease banks' regulatory burden, the Fed's EVM uses call report data, most of which is recorded at historical cost (rather than marked to market). The EVM aggregates balance sheet items into various categories, an example of which is shown in Table 1 for a hypothetical bank.[4] The model then matches each category with a proxy financial instrument—an instrument with a known market price that has a duration similar to those items in a given category—and assigns a "risk weight." The risk weight for each category is the estimated change in economic value of those items, given a 200-basis-point instantaneous rise in rates.[5] For example, the EVM places all fixed-rate mortgage products that reprice or mature in more than five years into the same category. In this example, the risk weight for that category is –8.50, indicating that the value of those mortgages are estimated to decline by 8.5 percent following an immediate 200-basis-point rate hike. The change in economic value is repeated for each balance sheet category. The predicted change in the economic value of equity, then, is the difference between the predicted change in assets and the predicted change in liabilities. The net change is scaled either by assets or equity. In this paper, we scale the change in equity by assets and refer to the output of the EVM as the "EVE" score. The example bank in Table 1 has an EVE score of –1.97; that is, the bank is expected to lose equity equal to 1.97 percent of assets when interest rates rise by 200 basis points.

The model's simplicity and generality make it a potentially powerful surveillance tool, but those same characteristics lead practitioners to question its usefulness. First, a precise economic-value-of-equity model would require an exact calculation of the duration for each financial instrument, which in turn requires detailed information on the cash flows and optionality of those instruments—data that the call reports do not contain. Because of this information limitation, the Fed's EVM may perform poorly for banks with a significant share of assets invested in complex instruments, such as collateralized mortgage obligations (CMOs) or callable securities, because their durations are more difficult to estimate.[6] Should interest rates fall, CMOs, for example, may mature much more quickly than anticipated by the EVM because homeowners will exercise their refinancing option. The maturity of core deposits may be another source of error. A community bank in a rural area with strong ties to its depositors may have a duration of demand deposits that is significantly longer than the duration at larger urban banks because the rural customers are less likely to withdraw their funds should market rates increase. A

[3] A number of financial textbooks discuss duration in detail. See, for example, Saunders and Cornett (2003).

[4] Table 1 is adapted from Wright and Houpt (1996). This table does not show the exact categories and risk weights used in the EVM.

[5] The (confidential) risk weights are derived by economists at the Board of Governors of the Federal Reserve System, and they do not change over our sample period.

[6] The EVM also fails to account for derivatives, another class of complex instruments. To avoid any bias from this source, we eliminate from our sample banks with derivatives.

## Table 1

### How Does an Accounting-Based Duration Model Work?

| | Total ($) (1) | Risk weight (%) (2) | Change in economic value ($) (1) x (2) |
|---|---|---|---|
| **Interest-sensitive assets** | | | |
| Fixed rate mortgage products | | | |
| 0-3 months | 0 | –0.20 | 0 |
| 3-12 months | 0 | –0.70 | 0 |
| 1-5 years | 0 | –3.90 | 0 |
| More than 5 years | 233,541 | –8.50 | –19,851 |
| Adjustable rate mortgage products | 2,932 | –4.40 | –129 |
| Other amortizing loans and securities | | | |
| 0-3 months | 0 | –0.20 | 0 |
| 3-12 months | 0 | –0.70 | 0 |
| 1-5 years | 28,858 | –2.90 | –837 |
| More than 5 years | 0 | –11.10 | 0 |
| Nonamortizing assets | | | |
| 0-3 months | 132,438 | –0.25 | –331 |
| 3-12 months | 7,319 | –1.20 | –88 |
| 1-5 years | 182,373 | –5.10 | –9,301 |
| More than 5 years | 11,194 | –15.90 | –1,780 |
| Total interest-sensitive assets | 598,655 | | –32,317 |
| All other assets | 85,696 | | |
| Total assets | 684,351 | | |
| **Interest-sensitive liabilities** | | | |
| Core deposits | | | |
| 0-3 months | 56,082 | 0.25 | 140 |
| 3-12 months | 39,634 | 1.20 | 476 |
| 1-5 years | 157,785 | 3.70 | 5,838 |
| 3-5 years | 50,600 | 7.00 | 3,542 |
| 5-10 years | 28,167 | 12.00 | 3,380 |
| CDs and other borrowings | | | |
| 0-3 months | 117,491 | 0.25 | 294 |
| 3-12 months | 77,303 | 1.20 | 928 |
| 1-5 years | 78,140 | 5.40 | 4,220 |
| More than 5 years | 0 | 12.00 | 0 |
| Total interest-sensitive liabilities | 605,204 | | 18,817 |
| Other liabilities | 112 | | |
| Total liabilities | 605,316 | | |
| **Summary** | | | |
| Change in assets values | | | –32,317 |
| Change in liability values | | | 18,817 |
| Net change in economic value | | | –13,500 |
| **Change in economic value as a percent of total assets** | | | **–1.97** |

SOURCE: Adapted from Wright and Houpt (1996).

second reason to question the applicability of the EVM is that a precise equity-at-risk calculation requires current market prices on all balance sheet items because the estimated change in the value of an asset or liability is equal to the duration multiplied by its price. Strictly speaking, the term "economic value" in this context is a misnomer because the EVM uses book values as estimates of market prices. A third weakness is that the EVM simulates just one interest rate scenario. Specifically, the model projects changes to a bank's economic value of equity given an instantaneous 200-basis-point upward parallel shift in the yield curve. The model does not account for changes in the slope of the yield curve, nor does it simulate a reduction in interest rates.

Despite these weaknesses, the Fed's EVM still may serve as a useful measure of interest rate sensitivity for community banks. Even if the actual EVE score of a given bank is imprecise, the ordinal ranking of banks by EVE scores may help supervisors detect the outlier banks that are vulnerable to an interest rate shock.

## MEASURING THE IMPACT OF RATE CHANGES WITH ACCOUNTING DATA

Tests of the ability of the EVM to measure interest rate sensitivity require assessments of bank performance following interest rate changes. The ideal performance indicator for testing the EVM is the change in the economic value of equity following a change in interest rates. In such a world, the ex post interest rate sensitivity of a bank could be measured via an econometric model by estimating the change in publicly traded equity due to the change in rates. Indeed, a number of studies have estimated in this manner the interest rate sensitivity of large banks.

Unfortunately, such data are available only for the approximately 300 bank holding companies with actively traded equity. To assess community bank performance following interest rate changes, we must rely exclusively on accounting information produced under generally accepted accounting principles (GAAP). Because we are limited to accounting data, our methodology simultaneously tests the usefulness of regulatory accounting information and the Fed's EVM. The adequacy of GAAP-based measures to capture interest rate risk is a question we leave for future research.

The accounting-based bank performance measures we utilize include changes in the NIM, return on assets (ROA), and the book value of equity (BVE). NIM is the ratio of net interest income divided by average earning assets, ROA (as defined here) is net income (before extraordinary items) divided by average assets, and BVE is simply the accounting value of total equity capital divided by total assets. The change in BVE is a straightforward, albeit imperfect, performance measure to assess the EVM because the EVM directly estimates the change in equity given an interest rate change. Unlike the economic value of equity, BVE will change slowly as items are gradually marked to market (recorded at market prices). The usefulness of NIM and ROA require further explanation.

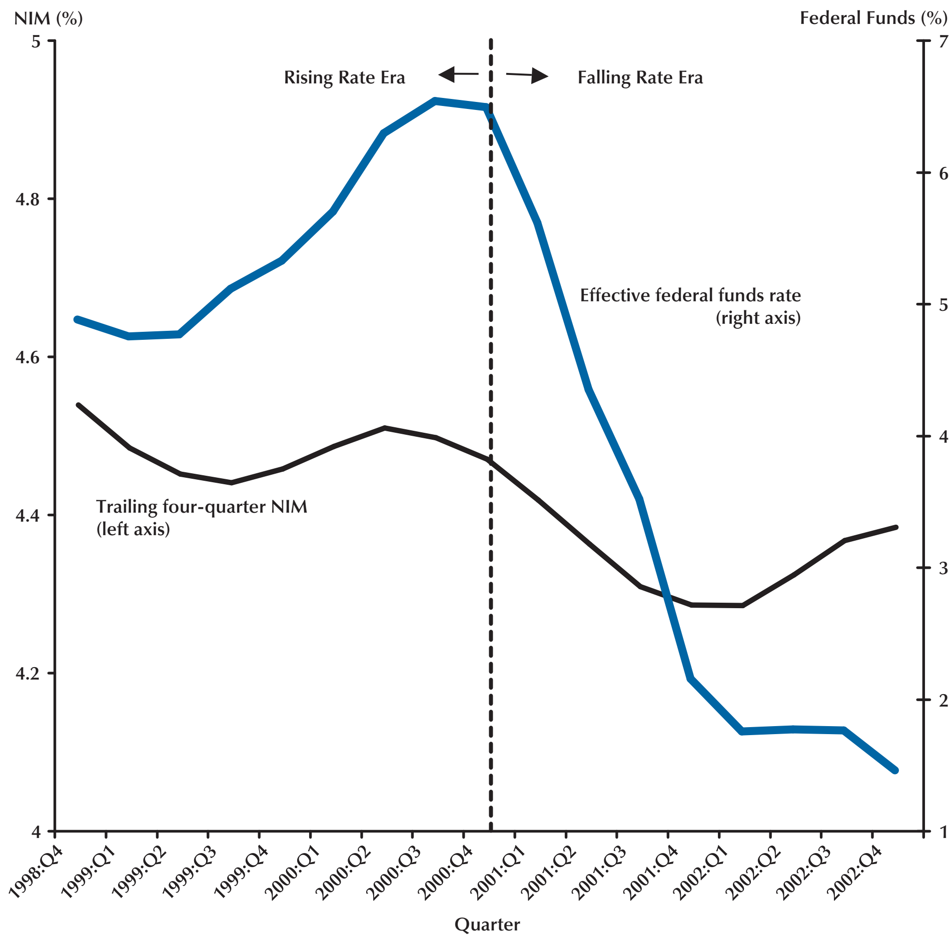
Although the theoretical link between earnings and a duration-based equity-at-risk model is somewhat loose, an empirical relationship should be discernable over a large number of observations. Banks that the EVM estimates to be vulnerable to rising interest rates (those with large negative EVE scores) are those that have weighted-average asset durations greater than weighted-average liability durations. When interest rates rise, assets decline in value more than liabilities, reducing the bank's economic capital. Because maturity is one component of duration, those same banks should be liability sensitive, on average, such that liabilities tend to mature or reprice faster than assets. In the short term, interest expense on liabilities will tend to increase more quickly than interest income on assets in a rising rate environment, reducing the NIM. The change in ROA captures not only the effect on NIM, but also any other noninterest impact of rate changes on earnings. Loan origination income might decline, for example, when interest rates rise, because refinancing activity slows. We expect, therefore, that banks with large negative values of EVE will exhibit a more pronounced deterioration in these income measures when interest rates rise, and those same banks will see a larger surge in income when interest rates fall.

A cursory look at bank NIMs suggests that banks are modestly rate sensitive. Figure 1 plots the effective federal funds rate on the right axis and the four-quarter moving average NIM on the left axis. We employ the four-quarter moving average to control for the seasonality in the data. Although the effective federal funds rate fluctuated by more than 400 basis points between 1998 and 2002, the average NIM of U.S. community banks changed little, staying within a range of about 20 basis points.[7]

[7] Clearly, this analysis is suggestive because other factors such as the 2001 recession may have affected NIM.

**Figure 1**

**NIM and the Effective Federal Funds Rate: Commercial Banks Are, on Average, Liability Sensitive**




NOTE: We plot the trailing four-quarter NIM for banks with less than $1 billion in total assets and the effective quarterly federal funds rate. The movement in NIM is consistent with commercial banks being modestly rate sensitive on average.

## EMPIRICAL ANALYSIS OF THE ECONOMIC VALUE MODEL

We test the ability of the Fed's EVM to distinguish interest rate sensitivity differences among U.S. community banks by comparing the measured interest rate sensitivity of the EVM with accounting performance measures. Observance of a bank's ex post experience of interest rate risk requires an interest rate change, a degree of rate sensitivity, and a time period sufficiently long enough for the interest rate risk to flow through the accounting data.[8]

To control for rate changes and time lags, we split the sample into two periods: a period of rising rates and a period of falling rates. Doing this, we ensure that the banks are hit by rate changes in the same direction, as opposed to offsetting rate changes. We chose the fourth quarter of 1998 through the fourth quarter of 2000 as the rising rate period and the fourth quarter of 2000 through the fourth quarter of 2002 as the falling rate period. The quarterly effec-

[8] Results not presented here indicate that the Fed's EVM, using quarterly accounting data, cannot distinguish effectively between banks with different rate sensitivities. This result is likely a combination of the accounting data that react with lags and low absolute levels of interest rate risk at most commercial banks. In tests using stock market returns, the Fed's EVM can distinguish among firms on a quarterly basis (Sierra, 2004).

tive federal funds rate increased 161 basis points in the first period and fell 503 basis points during the second period. Moreover, the yield curve steepened considerably in the falling rate period. The yield spread between the 10-year and 6-month Treasuries averaged 27 basis points between year-ends 1998 and 2000 and 235 basis points between year-ends 2000 and 2002. Yield spreads on Treasuries more consistent with bank asset and liability durations also increased in the later era. The spread between the 3-year and 1-year Treasuries averaged 27 basis points in the former period and 89 basis points in the later period. Hence, we should expect larger changes in bank performance measures during the falling rate era.

Our bank performance measures include the changes in NIM, ROA, and BVE over the relevant time period. We compute the changes in NIM and ROA using four-quarter averages to control for seasonality. For example, the rising interest rate environment begins in the fourth quarter of 1998 and ends in the fourth quarter of 2000. The change in NIM, then, is the trailing four-quarter NIM ending in the fourth quarter of 2000 less the trailing four-quarter NIM ending in the fourth quarter of 1998. We perform ordinary least-squares regression analysis, matched-pairs analysis, and correlation analysis with the "S" rating to test the EVM.

## *Bank Sample*

Our bank sample is split into the rising rate era and the falling rate era. We exclude banks with more than $1 billion in assets in any given quarter, de novo banks (those less than five years old), and banks that merged during the respective time period.[9] In addition, we eliminate the very smallest banks—those with less than $5 million in assets—and banks with measures that are extreme outliers, because these values fall outside of the realm of reasonable values for typical banks.[10] For each era, the sample contains about 6,000 banks and represents about 11 percent of all commercial banking assets. Descriptive statistics for the full-regression sample appear in Table 2.

As Table 2 reveals, changes in the accounting performance measures—the dependent variables—are modest. Mean NIM decreased 3 basis points in the rising rate era (Panel A) and fell again by 15 basis points in the falling rate era (Panel B). Changes in ROA were smaller, with ROA essentially unchanged in both the rising and falling rate eras. BVE declined by 2 basis points in the rising rate environment and increased by 22 basis points in the falling rate environment.

Table 2 also lists summary statistics for the independent variables, and EVE is the independent variable of primary interest. We multiply EVE by –1 to make its interpretation more intuitive. Because the Fed's EVE measure becomes more negative as the liability sensitivity of the bank increases, EVE and exposure to rising interest rates are inversely related. Flipping the sign on the EVE measure allows us to associate larger EVE values with greater exposure to rising interest rates. The mean EVE in Panel A of Table 2 is 0.87, which says that the average bank is predicted to lose 0.87 percent of its net economic asset value given a 200-basis-point parallel shift in the yield curve. The mean EVE in the falling rate era is 0.99 percent. The average sample bank, therefore, is estimated to be liability sensitive.

## *The Regression Model*

We use regression analysis to assess the average correlation between a bank's EVE and a change in NIM, net income, and BVE, for a given change in interest rates. EVE is computed as the average of each quarterly EVE value within the given time period. We use the average EVE value rather than the beginning-of-period EVE value because we are more interested in the correlation of EVE with the dependent variables, and less interested in the predictive power of EVE in a given quarter.[11] The average EVE score accounts for changes in EVE during the two-year sample period, an important factor if bank managers endogenously alter their interest rate sensitivity as interest rates begin to move in a particular direction. The EVE coefficient should be negative in the rising rate era because rising rates reduce earnings and equity at liability-sensitive banks. Con-

[9] Excluding banks involved in mergers potentially creates a survivorship bias. The bias would emerge if banks with high interest rate risk are involved in mergers to a greater extent than banks with low interest rate risk. We empirically examine this bias by comparing the average EVE scores of the merger banks in the quarters before merger with the average EVE scores of the sample banks. We find that the mean EVE scores from the two groups are not significantly different from one another, suggesting that survivorship bias is not important.

[10] We remove banks with NIM, ROA, BVE or nonperforming loans greater than the 99.75th percentile. We also remove banks with ROA below the 0.25th percentile. Banks with asset growth rates less than or equal to –100 percent are excluded. Finally, we exclude banks with a NIM, BVE, or nonperforming loan ratio less than zero.

[11] As a robustness check, we ran the regressions using beginning-of-period EVE and obtained qualitatively similar results.

## Table 2

### Descriptive Statistics of Regression Samples

**Panel A: Rising interest rate era, 1998:Q4–2000:Q4 (6,016 observations)**

| | Mean | Standard deviation | Minimum | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|---|---|
| NIM | 4.20 | 0.73 | 0.00 | 3.73 | 4.14 | 4.60 | 8.57 |
| ROA | 1.19 | 0.58 | –3.15 | 0.90 | 1.17 | 1.46 | 5.94 |
| BVE | 10.36 | 3.46 | 3.06 | 8.09 | 9.55 | 11.70 | 51.36 |
| Change in NIM | –0.03 | 0.47 | –4.81 | –0.24 | –0.03 | 0.19 | 4.69 |
| Change in ROA | –0.01 | 0.51 | –4.94 | –0.20 | –0.01 | 0.18 | 5.19 |
| Change in BVE | –0.02 | 1.59 | –20.38 | –0.66 | 0.01 | 0.67 | 21.49 |
| EVE | 0.87 | 1.24 | –3.26 | 0.03 | 0.78 | 1.57 | 8.85 |
| NPL | 0.56 | 0.67 | 0.00 | 0.11 | 0.34 | 0.76 | 6.06 |
| LNTA | 11.22 | 0.94 | 8.59 | 10.56 | 11.20 | 11.85 | 13.81 |
| AGR | 11.35 | 12.32 | –92.49 | 3.97 | 10.09 | 17.66 | 86.07 |

**Panel B: Falling interest rate era, 2000:Q4–2002:Q4 (5,773 observations)**

| | Mean | Standard deviation | Minimum | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|---|---|
| NIM | 4.18 | 0.77 | 0.24 | 3.69 | 4.11 | 4.60 | 8.74 |
| ROA | 1.20 | 0.62 | –3.25 | 0.86 | 1.17 | 1.50 | 7.86 |
| BVE | 10.38 | 3.52 | 4.51 | 8.02 | 9.44 | 11.77 | 51.24 |
| Change in NIM | –0.15 | 0.63 | –5.98 | –0.45 | –0.10 | 0.21 | 4.42 |
| Change in ROA | –0.02 | 0.58 | –5.63 | –0.25 | 0.00 | 0.25 | 5.64 |
| Change in BVE | 0.22 | 1.54 | –16.56 | –0.44 | 0.27 | 0.97 | 10.59 |
| EVE | 0.99 | 1.25 | –3.54 | 0.15 | 0.86 | 1.70 | 10.10 |
| NPL | 0.66 | 0.77 | 0.00 | 0.13 | 0.41 | 0.91 | 6.41 |
| LNTA | 11.34 | 0.95 | 8.67 | 10.69 | 11.32 | 12.00 | 13.80 |
| AGR | 12.64 | 11.92 | –86.17 | 5.78 | 11.67 | 18.71 | 78.62 |

NOTE: Change in NIM: the trailing four-quarter NIM at the end of the period less the trailing four-quarter NIM at the start of the period. Change in ROA: the trailing four-quarter ROA at the end of the period less the trailing four-quarter ROA at the start of the period. Change in BVE: BVE at the end of the period less BVE at the start of the period. EVE: average over all quarters in the given era of Fed EVE score scaled by total assets. NPL: average nonperforming loans to total assets in the given era. LNTA: the natural log of average total assets in the given era. AGR: the growth rate of total assets during the given era.

versely, the EVE coefficient should be positive in the falling rate era.

In the regressions, we attempt to control for factors other than interest rate changes that could influence income and equity ratios. Specifically, we include the ratio of nonperforming loans to total assets (NPL)—loans that are 90 days or more past due or are no longer accruing interest—as a credit risk control variable because nonperforming loans can directly and indirectly affect all three dependent variables. Most nonperforming loans do not accrue interest, which means that interest income, and hence NIM and ROA, are lower than they otherwise would be. In addition, a higher ratio of nonperforming loans may be associated with changes in asset quality, which would cause a bank to set aside more provisions and lower ROA. Finally, the change in BVE is smaller if net income and, hence, retained earnings are smaller. We expect the signs of the nonperforming loans coefficients to be negative in both the rising and falling rate periods. The mean nonperforming loan-to-total-asset ratio is 0.56 percent in Panel A of Table 2 and 0.66 percent in Panel B of Table 2.

We also control for bank size by including the natural log of total assets in the regression. NIM, net income, and BVE may respond to the economic environment differently at larger banks than at smaller banks. For example, changes in interest rates may trigger the use of lines of credit, which are more prevalent at larger institutions. The sign of this coefficient could be positive or negative.

Asset growth is an explanatory variable that controls for portfolio turnover. More rapid asset growth brings assets and liabilities onto the books faster at market prices, which may either exacerbate or dampen the sensitivity of earnings and BVE to changes in interest rates. Asset growth will exacerbate interest rate sensitivity if the new assets and liabilities reinforce or increase the bank's interest rate position. Conversely, asset growth will dampen sensitivity if the new assets and liabilities mitigate the bank's interest rate position. The average EVE score will partially capture these asset-growth effects, but the EVE scores are not asset weighted. The signs of the asset-growth coefficients, therefore, are uncertain. Table 2 shows that banks grew quickly in each sample period. The mean growth rate in the rising rate era is 11.35 percent; asset growth in the falling rate era is 12.64 percent. The standard deviation of asset growth is also quite large, exceeding 11 percent in both rate eras.

We use ordinary least squares to run cross-sectional regressions on the following model:

(1)
$$\Delta Y_i = \alpha_0 + \alpha_1 EVE_i + \alpha_2 NPL_i + \alpha_3 LNTA_i + \alpha_4 AGR_i + \varepsilon_i,$$

where $\Delta Y_i$ represents the change in the dependent variable (NIM, ROA, or BVE) of bank *i*, *LNTA* is the natural log of total assets, and *AGR* is asset growth. The dependent variables are computed as the end-of-period value less the beginning-of-period value, while the independent variables (except asset growth) are the quarterly averages over the time period. Asset growth is simply the percentage change in assets over the period. We report two specifications of equation (1). Model 1 excludes asset growth; model 2 includes asset growth. For both models, the primary focus is on the EVE coefficient.

## Regression Results

Regression results in Table 3 show that the Fed's EVM is indeed correlated with the accounting performance measures. In the rising rate era, we expect the high-EVE banks to perform worse than low-EVE banks. Specifically, the EVE coefficient should be negative for each regression presented in Panel A of Table 3. Across the columns of the EVE row in Panel A, the EVE coefficients are negative and statistically significant for every specification and every dependent variable. The results from model 2 indicate that a bank with an EVE score 1 percentage point higher than another bank would experience, all else equal, a drop in NIM, ROA, and BVE equal to 5.0, 5.4, and 18.5 basis points, respectively, over the two-year period. Put another way, the results imply that for the average bank, which has an EVE score of 0.87, NIM, ROA, and BVE were about 4.4 ($5.0 \times 0.87$), 4.7, and 16.1 basis points lower, respectively, than they would have been had the bank had an EVE score of zero. The results in Panel A are consistent with the ability of the Fed's EVM to identify a bank's sensitivity to rising rates.

In the falling rate era, high-EVE banks are projected to be more liability sensitive such that the high-EVE banks should perform better than low-EVE banks. If EVE is able to distinguish effectively between banks with high and low liability sensitivity, the EVE coefficients should be positive in Panel B of Table 3. Across the columns of the EVE row in panel B, the EVE coefficients are positive and statistically significant for both model specifications and each dependent variable. The EVE coefficients imply that changes in NIM, ROA, and BVE over the two-year period are expected to increase 15.2, 8.6, and 3.7 basis points, respectively, for each 1-percentage-point increase in EVE. The results in Panel B are consistent with the ability of the Fed's EVM to identify banks that are the most sensitive to falling interest rates.

The EVE coefficients for NIM and ROA are much larger in Panel B of Table 3 than in Panel A, a result that most likely reflects the greater interest rate changes in the falling rate era. Recall that the federal funds rate fell 503 basis points in the falling rate era, which is 4.3 times the 116-basis-point rise in the rising rate era. In addition, the average yield spread between the 1- and 3-year Treasuries increased 3.5 times relative to the rising rate era. According to model 2, a bank with an EVE score 1 percentage point higher than another bank in the rising rate era

## Table 3

### Regression Analysis of the Fed's Economic Value Model

**Panel A: Rising Interest Rate era, 1998:Q4–2000:Q4 (6,016 observations)**

| | Dependent Variable | | | | | |
|---|---|---|---|---|---|---|
| | Change in NIM | | Change in ROA | | Change in BVE | |
| Variable | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| Intercept | 0.656 | 0.421 | 0.230 | 0.098 | 1.051 | –0.344 |
| (p value) | (0.000) | (0.000) | (0.002) | (0.205) | (0.000) | (0.000) |
| EVE | –0.044 | –0.050 | –0.051 | –0.054 | –0.149 | –0.185 |
| (p value) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| NPL | –0.018 | –0.028 | –0.111 | –0.116 | 0.021 | –0.034 |
| (p value) | (0.017) | (0.001) | (0.000) | (0.000) | (0.051) | (0.001) |
| LNTA | –0.057 | –0.026 | –0.012 | 0.005 | –0.084 | 0.095 |
| (p value) | (0.000) | (0.000) | (0.072) | (0.472) | (0.000) | (0.000) |
| AGR | | –0.008 | | –0.005 | | –0.049 |
| (p value) | | (0.000) | | (0.000) | | (0.000) |
| Adjusted $R^2$ | 0.03 | 0.07 | 0.03 | 0.05 | 0.02 | 0.15 |

**Panel B: Falling Interest Rate era, 2000:Q4–2002:Q4 (5,773 observations)**

| | Dependent Variable | | | | | |
|---|---|---|---|---|---|---|
| | Change in NIM | | Change in ROA | | Change in BVE | |
| Variable | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| Intercept | –0.285 | –0.467 | –0.311 | –0.303 | –0.488 | –1.773 |
| (p value) | (0.005) | (0.000) | (0.002) | (0.004) | (0.000) | (0.000) |
| EVE | 0.155 | 0.152 | 0.086 | 0.086 | 0.058 | 0.037 |
| (p value) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| NPL | –0.013 | –0.028 | –0.116 | –0.115 | 0.029 | –0.071 |
| (p value) | (0.266) | (0.020) | (0.000) | (0.000) | (0.014) | (0.000) |
| LNTA | –0.001 | 0.025 | 0.025 | 0.024 | 0.056 | 0.235 |
| (p value) | (0.945) | (0.012) | (0.006) | (0.018) | (0.000) | (0.000) |
| AGR | | –0.007 | | 0.000 | | –0.052 |
| (p value) | | (0.000) | | (0.770) | | (0.000) |
| Adjusted $R^2$ | 0.09 | 0.11 | 0.07 | 0.07 | 0.00 | 0.15 |

NOTE: We regress three different measures of ex post interest rate sensitivity on the Fed's ex ante measure of interest rate sensitivity (EVE), nonperfoming loans (NPL), log of total assets (LNTA) and asset growth rate (AGR). The three dependent variables are change in net interest margin (NIM), change in return on assets (ROA), and change in book value of equity (BVE). The coefficient on the EVE variable is the focus of the regression analysis.

We divide the sample period into two eras. The first era is from the fourth quarter of 1998 through the fourth quarter of 2000 and is a time period during which interest rates were more-or-less uniformly increasing. The second era is from the fourth quarter of 2000 through the fourth quarter of 2002 and is a time period during which interest rates were more-or-less uniformly falling. Banks that the Fed's model predicts are more liability sensitive should perform worse over the rising rate era, and the EVE coefficients in Panel A should be negative, which they are. Banks that the Fed's model predicts are more liability sensitive should perform better over the decreasing rate era, and the EVE coefficients in Panel B should be positive, which they are. P values are corrected for heteroskedasticity.

(Panel A) experiences a 5.0-basis-point drop in NIM. However, in the falling rate era (Panel B) a bank with an EVE score 1 percentage point higher than another bank experiences a NIM increase of 15.5-basis-point increase, 3.1 times the change in the rising rate era. Moreover, ROA in the falling rate era increased by 1.6 times (8.6 divided by 5.4) the change in the rising rate era. The BVE results, however, do not show the same pattern in magnitude between Panels A and B. The EVE coefficient for the BVE in the falling rate era changed by just 0.2 times the change in the rising rate era.

With a few exceptions, the coefficients on the control variables have the expected signs. Nonperforming loan coefficients are negative in 10 of 12 regressions and statistically significant at the 5 percent level or lower in 9 regressions. The coefficients on bank size (natural log of total assets) suggest that, all else equal, larger banks have amplified swings in income and equity relative to smaller banks. With three exceptions, the coefficients on the natural log of total assets are negative in the rising rate era and positive in the falling rate era, implying that NIM, ROA, and BVE at the larger banks move in the same direction as the interest rate risk. Finally, the coefficients on asset growth are negative and statistically significant in the rising rate era, but remain negative in the falling rate era for all the specifications except that with ROA as the dependent variable. These results suggest that asset growth increased interest rate sensitivity in the rising rate era but partially offset the interest rate sensitivity in the falling rate era.

## Matched-Pairs Analysis

Although regression analysis describes the average relationship between EVE and accounting performance measures, we are also interested in the ordinal properties of the EVM. Can the EVM separate the riskiest banks from the safer ones? This question is important to Federal Reserve examiners and supervisors because they use the model to help assess interest rate risk at a large number of community banks. The model may help them detect banks in the riskiest tail of the distribution.

We begin the matched-pairs analysis by separating the same sample of community banks used in the regression analysis into deciles based on their predicted exposure to rising interest rates as measured by their average EVE score. We then compare changes in the performance measures across deciles. By grouping the banks into deciles, we are exploring whether the EVM broadly ranks banks by interest rate risk, allowing for the possibility that the ordinal rankings within a given decile may not be very tight. Banks that are the most liability sensitive are in the top deciles, whereas banks with low liability sensitivity or those that are asset sensitive (exposed to falling rates) are in the bottom deciles. This ranking does not imply that banks in the bottom deciles have low interest rate risk because such banks may be extremely asset sensitive. Interest rate risk is best captured by the absolute value of the EVE measure.

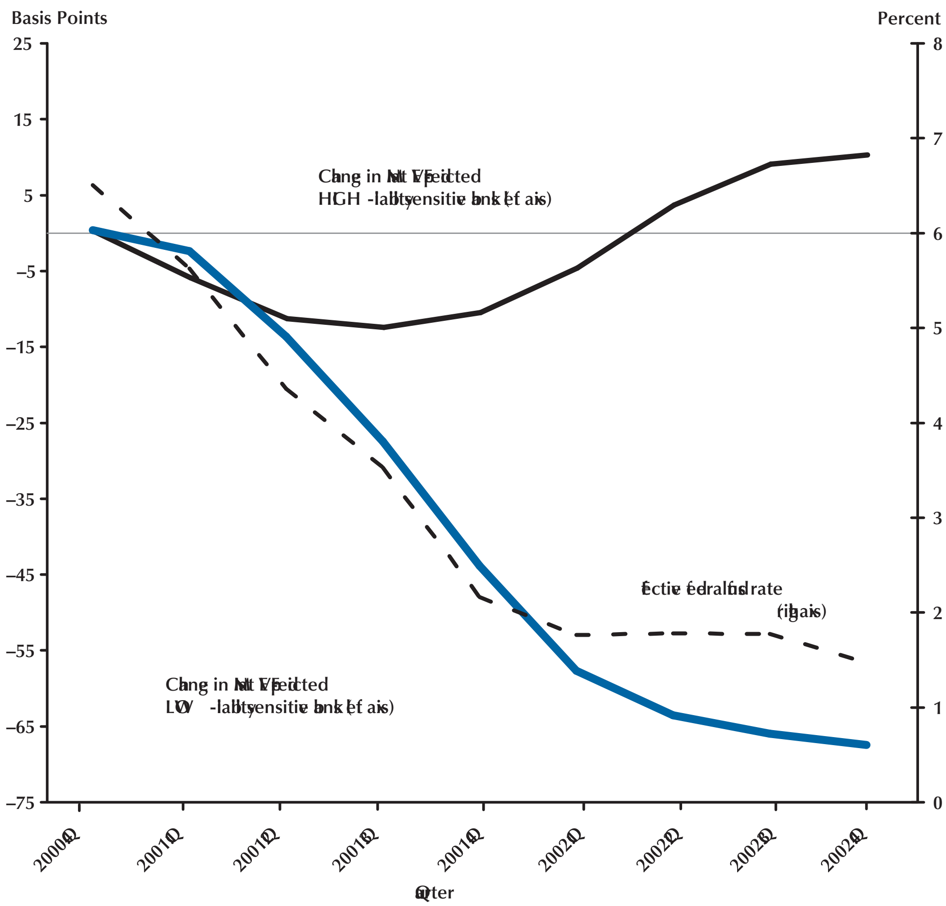
We compare bank performance in the top decile (the most liability-sensitive banks) with banks in consecutively lower deciles. Based on two characteristics, each bank in the top decile is matched with banks in lower deciles. Total assets at the match bank must be within 50 percent of the sample bank to control for the influence of size on performance ratios, and the nonperforming loan-to-total-asset ratios must be within 12.5 basis points to ensure that differences in nonaccruing loans do not unduly account for the banks' differences in NIM and ROA. If several banks qualify as matches with a bank in the top decile, we average the performance ratios of the matching banks.

To visualize the different reactions to falling interest rates, we plot in Figure 2 the average cumulative change in NIM by quarter of the banks in the top decile and the average cumulative change in NIM of the banks in the bottom decile. The average NIM at the most liability-sensitive banks declines during the first three quarters—probably due to the lag from the rising interest rate environment in 2000—and then begins to climb in the third quarter of 2001. In contrast, the average NIM at the least liability-sensitive banks declines continuously between the fourth quarter of 2000 and the fourth quarter of 2002. By the fourth quarter of 2002, the difference in the change in NIM between the top decile and the bottom decile is about 78 basis points. Most of that difference is due to falling NIMs at the least liability-sensitive banks; rising NIMs at the most liability-sensitive banks account for only about 10 basis points of the total difference.

In addition to Figure 2, we conduct a series of *t*-tests on the differences in means between the most liability-sensitive banks and progressively less liability-sensitive match-banks, for both the rising interest rate environment and the falling interest rate environment. The results appear in Table 4. Panel A

## Figure 2

### Changes in NIM at EVE-Predicted High- and Low-Liability-Sensitive Banks




We plot the average change in net interest margin (NIM) for high EVE and low EVE banks for the falling rate time period. The figure shows that high EVE banks are indeed more liability sensitive than low EVE banks. Furthermore, the direction of change is consistent with EVM predictions; high EVE banks' NIM improve, while low EVE banks' NIM decrease. The chart also plots the effective federal funds rate on the right axis.

lists the results for the rising rate era, whereas Panel B lists the results for the falling rate era. The first row of each panel compares the average changes in NIM, ROA, and BVE of banks in the top (tenth) decile with the average changes for banks in the ninth decile; the second row compares the top decile with the eighth decile; and so on. We expect the differences to widen as the deciles in the comparison widen.

With some notable exceptions, the matched-pair results indicate that the Fed's EVM detects relatively fine quantitative differences in interest rate risk across deciles. The distinctions are the most pronounced for NIM and ROA in the falling rate environment, reported in Panel B of Table 4. We expect the differences in changes in NIM and ROA to widen (become more positive) as the deciles compared become more extreme, because banks that are less liability sensitive will respond less favorably to a drop in rates compared with banks that are more liability sensitive. Indeed, the spread does widen as the gaps between the deciles widen, and the differences in the changes are statistically different from zero at the 5 percent level or lower for every comparison. Differences in the changes of BVE are less robust. In fact, differences in BVE changes have the wrong signs in five of nine comparisons of Panel B.

## Table 4

### Relative Interest Rate Sensitivity of Pairs Matched by Extremity of the Fed's EVE Model Interest Rate Sensitivity Prediction

**Panel A: Rising interest rate era, 1998:Q4–2000:Q4**

| Decile | N | Change in NIM | Difference in NIM changes | Change in ROA | Difference in ROA changes | Change in BVE | Difference in BVE changes |
|---|---|---|---|---|---|---|---|
| 10<br>9 | 595 | –11.18<br>–9.60 | –1.58 | –8.08<br>–6.30 | –1.79 | –43.55<br>–8.59 | –34.96*** |
| 10<br>8 | 595 | –11.30<br>–8.58 | –2.72 | –8.29<br>–3.37 | –4.92** | –45.18<br>–16.41 | –28.77*** |
| 10<br>7 | 598 | –10.92<br>–5.05 | –5.87*** | –8.13<br>–3.11 | –5.01** | –44.81<br>–5.99 | –38.81*** |
| 10<br>6 | 594 | –11.04<br>–6.57 | –4.48*** | –8.48<br>1.28 | –9.76*** | –45.75<br>–0.87 | –44.88*** |
| 10<br>5 | 599 | –10.98<br>–3.70 | –7.28*** | –8.25<br>0.46 | –8.70*** | –44.78<br>–2.41 | –42.37*** |
| 10<br>4 | 595 | –10.85<br>–4.08 | –6.78*** | –7.76<br>–1.34 | –6.42*** | –44.40<br>2.40 | –46.79*** |
| 10<br>3 | 597 | –11.16<br>6.46 | –17.63*** | –8.44<br>4.57 | –13.02*** | –43.69<br>7.56 | –51.24*** |
| 10<br>2 | 598 | –11.05<br>1.32 | –12.37*** | –7.89<br>4.43 | –12.32*** | –42.86<br>8.24 | –51.10*** |
| 10<br>1 | 597 | –10.97<br>12.72 | –23.68*** | –8.79<br>14.78 | –23.57*** | –43.49<br>35.80 | –79.29*** |

**Panel B: Falling interest rate era, 2000:Q4–2002:Q4**

| Decile | N | Change in NIM | Difference in NIM changes | Change in ROA | Difference in ROA changes | Change in BVE | Difference in BVE changes |
|---|---|---|---|---|---|---|---|
| 10<br>9 | 571 | 9.72<br>4.02 | 5.70** | 14.33<br>8.50 | 5.82*** | 25.34<br>32.68 | –7.34 |
| 10<br>8 | 569 | 9.93<br>–1.21 | 11.14*** | 14.74<br>7.14 | 7.59*** | 25.22<br>26.26 | –1.04 |
| 10<br>7 | 570 | 9.84<br>–5.19 | 15.03*** | 14.71<br>3.39 | 11.32*** | 24.90<br>29.03 | –4.12 |
| 10<br>6 | 567 | 10.09<br>–6.65 | 16.75*** | 14.92<br>4.93 | 9.99*** | 25.31<br>32.65 | –7.33 |
| 10<br>5 | 572 | 9.78<br>–8.37 | 18.15*** | 14.53<br>1.25 | 13.28*** | 25.00<br>20.16 | 4.84** |
| 10<br>4 | 572 | 9.67<br>–19.17 | 28.85*** | 14.37<br>1.25 | 13.11*** | 24.99<br>23.90 | 1.09 |
| 10<br>3 | 569 | 9.93<br>–16.66 | 26.59*** | 14.55<br>–0.46 | 15.01*** | 25.09<br>15.14 | 9.95 |
| 10<br>2 | 572 | 9.34<br>–33.81 | 43.15*** | 14.26<br>–9.38 | 23.64*** | 24.69<br>10.06 | 14.63* |
| 10<br>1 | 571 | 10.19<br>–65.79 | 75.98*** | 14.45<br>–28.76 | 43.21*** | 25.18<br>–2.56 | 27.74*** |

NOTE: Values are in basis points. */**/*** indicate significance at the 10/5/1 percent levels, respectively. In this table, we divide community banks into deciles based upon their degree of liability sensitivity. We then match banks in the top decile with similar banks in the lower decile. With few exceptions, we find that the more liability-sensitive banks perform more poorly in the rising rate era, but they perform better in the falling rate era. These results show that the Fed's EVM accurately separates banks by their interest rate sensitivity. The banks in the higher (lower) deciles are predicted to be the most (least) liability sensitive.

Only for three of the comparisons in Panel B are the results statistically significant and have the expected sign.

The matched-pair results for NIM and ROA in the rising rate era are not as dramatic as the results in the falling rate era, but the results for the BVE are much stronger than those of the falling rate era. The rising rate era results appear in Panel A of Table 4. We expect the differences in the changes in NIM, ROA, and BVE to become more negative as the decile comparisons widen, because the most liability-sensitive banks in the top decile should have larger declines in these performance measures relative to less liability-sensitive banks. All of the differences of the changes in NIM, ROA, and BVE have the expected signs, and they generally become more negative as the decile differences widen. In addition, most are statistically significant at the 1 percent level. Results for the BVE show that banks in the top decile experienced a drop in equity of 43.55 basis points, whereas banks in the ninth decile had a drop in equity of 8.59 basis points. The –34.96-basis-point difference is statistically significant at the 1 percent level. The differences in the changes of BVE generally become more negative, as expected, such that the spread between the top and bottom deciles is more than –79 basis points.

In sum, matched-pair analysis indicates that the Fed's EVM can detect differences in interest rate risk when banks are grouped by deciles according to their exposure to rising interest rates. These results confirm the robustness of the regression results and suggest that bank supervisors can use the EVM as a useful tool to rank community banks by interest rate sensitivity.

## Correlation with the "S" Rating

Each time a bank is examined, examiners assign the bank a sensitivity (S) rating from 1 to 5, with 1 being the best rating. A strong and positive correlation between the EVE score and the S rating would be consistent with the assertion that the EVM captures information about a bank's interest rate risk. This analysis also serves as a robustness check against the prior tests, which rely solely on accounting numbers.

We assess the correlation between EVE and S ratings both in decile groupings and on a bank-by-bank basis. As with matched pairs, the decile analysis allows for the possibility that the EVE rankings within a given decile may not be very tight. We rank all the community banks in our sample by their EVE scores and split the banks into deciles. We then compute the mean EVE and S ratings and rank the deciles by the absolute value of each decile. If the EVE model is calibrated such that banks with the lowest interest rate risk have EVE scores near zero, then banks with large absolute-value EVE scores should have relatively worse (higher) examiner ratings. The top half of Table 5 lists the mean EVE score and the mean S rating for each decile, listed in descending order by the absolute value of the mean EVE score.

The correlation coefficients listed in the bottom half of Table 5 show a consistent positive relationship between the absolute value of EVE scores and S ratings. The correlation coefficient on a decile basis is 0.99, and it is 0.14 on a bank-by-bank basis. Both are statistically different from zero at the 1 percent level. The high degree of correlation suggests that either the EVM captures information about interest rate risk that examiners confirm on site or the examiners use the EVM to help assess interest rate risk.

Even though Federal Reserve examiners are instructed not to incorporate the EVM directly into the S rating, one may be skeptical. One simple test to help discern the direction of causation between EVE and S ratings is to examine the correlation between EVE scores and S ratings in 1998. Because 1998 was the first year that the Focus reports were made available to examiners, a period of transition undoubtedly took place for the examiners to learn about and understand the report. A positive correlation in 1998 would add to the evidence that the EVM captures information that examiners confirm on site. At the bottom of Table 5 we report the correlation coefficient between EVE scores and S ratings assigned in 1998. The decile correlation is 0.82 and the bank-level correlation is 0.10. Again, both are statistically different from zero at the 1 percent level. The results for 1998 lend support to the hypothesis that the EVM contains information about interest rate sensitivity that examiners affirm when they are on site at a particular bank.

## CONCLUSION

Regression analysis, matched pairs, and correlation analysis demonstrate that the Fed's EVM is a useful supervisory tool to assess the relative interest rate risk at community banks. Bank supervisors can confidently use the model's output to rank banks by interest rate sensitivity. The model appears to be quite stable and robust. Although the EVM was

**Table 5**

**The Relationship Between the EVM and the "S" Ratings**

| Decile by absolute value of EVE | Mean S rating by decile | Mean EVE of decile | Observations |
|---|---|---|---|
| 10 | 1.83 | 3.44 | 3,716 |
| 9 | 1.73 | 2.22 | 3,715 |
| 8 | 1.67 | 1.68 | 3,715 |
| 7 | 1.64 | 1.28 | 3,715 |
| 6 | 1.62 | –1.12 | 3,715 |
| 5 | 1.61 | 0.95 | 3,715 |
| 4 | 1.56 | 0.64 | 3,715 |
| 3 | 1.58 | –0.37 | 3,715 |
| 2 | 1.56 | 0.34 | 3,715 |
| 1 | 1.56 | 0.02 | 3,715 |

**Correlation coefficient of absolute value of EVE and S ratings**

| | By decile | Bank level |
|---|---|---|
| Full sample | 0.99*** | 0.14*** |
| 1998 | 0.82*** | 0.10*** |

NOTE: ***Indicates significance at the 1 percent level or better. We measure the correlation between the absolute value of the EVE measure and a bank's S rating. The EVE measure and S ratings are positively correlated at a decile and bank level. The results show that either the Fed's EVM identifies interest rate risk patterns that examiners confirm on site or that examiners use the EVM to assign the S rating.

constructed assuming a parallel yield curve shift upward of 200 basis points, our results demonstrate that the model is useful in both rising and falling interest rate eras and in time periods in which the slope of the yield curve changes.

Another conclusion that emerges from these results is that the average interest rate risk at community banks appears to be modest. Even relatively big changes in interest rates such as the drop that occurred between December 2000 and December 2002 had relatively small effects on income and capital at community banks, both in absolute and relative terms. For example, regression analysis predicts that the average bank with an EVE score of 0.99 experienced an increase in NIM of about 15 basis points, an increase in ROA of 9 basis points, and an increase in BVE of 4 basis points over the two-year period of falling rates. Although nontrivial, none of these changes by themselves are of sufficient magnitude to affect bank performance significantly. Consequently, interest rate risk does not appear to be a significant threat to bank safety and soundness at the present time, a conclusion that should provide some comfort to monetary policymakers when they influence interest rates.

One caveat to this conclusion is that our analysis fails to consider the interaction between interest rate risk and other risks, such as credit risk. A large change in the level of interest rates may affect community banks more severely than our analysis suggests because the default rates of marginal borrowers with variable rate payments may increase.

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# Discrete Policy Changes and Empirical Models of the Federal Funds Rate

Michael J. Dueker and Robert H. Rasche

In macroeconomic models with monthly or quarterly data, it is common to assume that variables—such as output, investment, and inflation—respond to the monthly or quarterly average of the daily federal funds rate. The idea is that the cumulative flow of investment spending within a quarter, for example, does not depend on the value of the federal funds rate at a point in time but, instead, on its average level throughout the quarter. In fact, the use of the monthly or quarterly average of the federal funds rate is common practice in a variety of empirical macroeconomic models, from vector autoregressions (e.g., Bernanke and Blinder, 1992) to estimated versions of stochastic dynamic general equilibrium models (e.g., Lubik and Schorfheide, 2004). In addition, the daily effective federal funds rate contains noise in the form of departures from the target level set by monetary policymakers, as a result of idiosyncratic conditions in the interbank loan market on a given day. Averaging the daily rates across a month or quarter is one way to cancel most of this noise—and is yet another reason why the use of monthly and quarterly averages has become a widely used measure of monetary policy. Hence, regardless of the direction of the evolution of empirical macroeconomics, the use of the monthly or quarterly average of the daily federal funds rate will likely remain common practice.

Another feature common to otherwise disparate approaches to macroeconomic modeling is that the federal funds rate has its own equation called the policy equation. Because Federal Reserve policymakers use the federal funds rate as their policy instrument, one equation in the model describes the way that policymakers adjust the policy instrument in response to the current state of the economy. In practice, monetary policymakers adjust a target level for the federal funds rate by discrete increments at their regularly scheduled meetings or in conference calls. One often-neglected consequence of quarterly averaging is that any change in the target federal funds rate will affect the quarterly average in two different quarters. For example, if policymakers raise the target by 50 basis points precisely halfway through this quarter, then the current quarter's average will rise by 25 basis points relative to last quarter, and next quarter's average will also exceed this quarter's average by 25 basis points, all else equal. Note that this calculation relies on a key feature of target changes: They are in effect until further notice and not for a specified time period. In other words, monetary policymakers could announce a 25-basis-point increase in the target federal funds rate that would be in effect for the next 60 days, but this is not what they do. Instead, each target change is in effect until further notice. Hence, a target change made now is likely to persist into the following quarter.

Despite this clear source of predictable change in the quarterly average of the federal funds rate, the vast bulk of the literature that estimates policy equations ignores information concerning the timing and magnitude of discrete changes to the target federal funds rate. As a result, such empirical models end up trying to predict the effect on the monthly or quarterly average of known, past policy actions rather than include this piece of data in the forecast information set. While this information about discrete target changes might seem like a second-order issue in the estimation of policy equations, we present estimates of a Taylor-type policy equation (Taylor, 1993) that suggest otherwise. It turns out that policy equations of the quarterly average of the federal funds rate that take account of discrete changes to the target federal funds rate fit the data substantially better than those that omit this information. In addition, we show that empirical results on important policy questions can be overturned, depending on whether a discreteness-adjustment

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term is included in the estimation of a policy equation. In particular, we focus in this paper on a debate concerning the source of interest rate smoothing—an issue discussed in greater detail in the next section. Given the results in this paper, we recommend that such a discreteness-adjustment term be included as a regular feature of empirical models of the quarterly or monthly average of the federal funds rate.

## THE DEBATE ON INTEREST RATE SMOOTHING IN ESTIMATED POLICY EQUATIONS

One lively debate in empirical macroeconomics is whether monetary policymakers adjust the federal funds rate gradually in response to developments in the economy or, alternatively, whether the determinants of the interest rate evolve gradually enough to account for the sluggish pace of observed changes in the interest rate. Sack (2000) and Clarida, Galí, and Gertler (2000) argue for the former; Rudebusch (2002) argues for the latter; English, Nelson, and Sack (2003) find evidence of both. This question can be summarized as follows: Do policymakers smooth the interest rate by overtly choosing to adjust it gradually? Three reasons have been put forth for rate smoothing and partial adjustment. First, policymakers are uncertain about the true structure of the economy and this source of possible policy mistakes leads them to act less forcefully in the short run (Sack, 2000). Second, and similarly, policymakers are uncertain about the accuracy of initial data releases—another source of possible policy mistakes (Orphanides, 2001). Third, and perhaps most relevant, is the idea from Woodford (2003) that monetary policymakers can influence market expectations if they show a willingness to implement—even through gradual actions—a large long-run interest rate response if necessary. For example, suppose that policymakers indicate that they are willing to raise the federal funds rate by an eventual amount of 120 basis points if a 40-basis-point increase in inflation persists. Policymakers demonstrate this willingness by embarking on a path of raising the interest rate gradually. If the public believes that this gradual path will be implemented for as long as necessary to reduce inflation, market expectations will adjust quickly, with the beneficial effect of reducing inflation without requiring much actual increase in the interest rate.

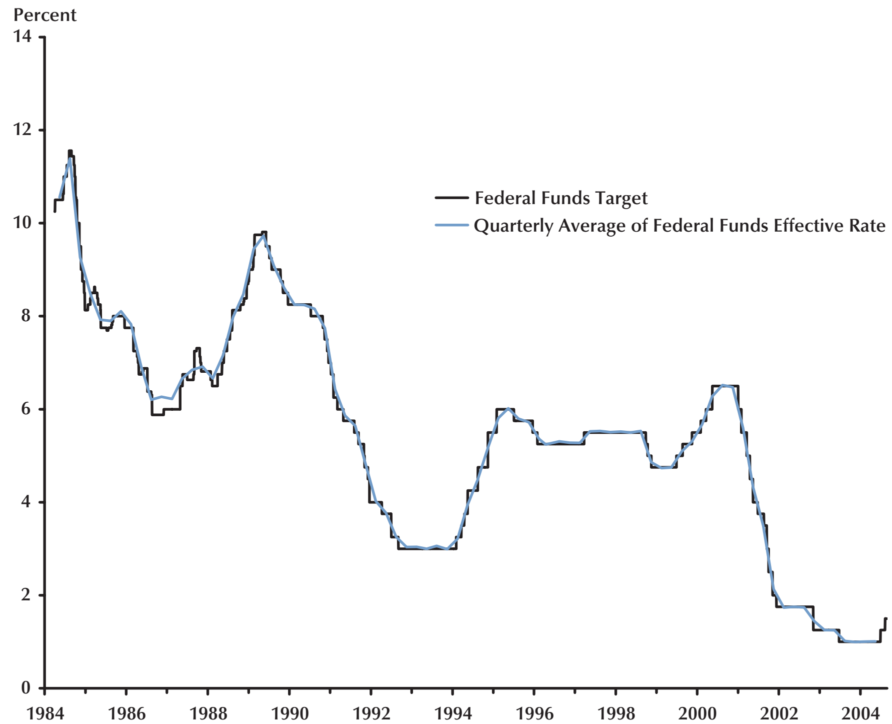
A dissenting voice to the interest rate smoothing argument is Rudebusch (2002), who suggests that episode-specific factors influence the setting of monetary policy and are not captured by simple empirical policy equations. For example, the credit crunch in the early 1990s, the financial market upset in 1998, and the terrorist attacks on September 11, 2001, all created uncertainties that had a persistent influence on the level of the federal funds rate, yet they are not incorporated in simple policy equations. Rudebusch suggests that purported evidence of interest rate smoothing is actually only a product of omitted variable bias. Since it is not really possible to include or even measure all of the relevant variables in an interest rate regression, Rudebusch (2002) concludes that the lagged policy rate (a measure of interest rate smoothing) can be included in regressions but should not be interpreted as a structural feature of monetary policy practice.

To disentangle these two competing hypotheses, English, Nelson, and Sack (2003) studied a specification for a policy rule that can nest these two interpretations of Federal Reserve policy. Their results suggest a significant role for both interpretations, although their analysis indicated that interest rate smoothing was perhaps the most important factor quantitatively. In this article, we demonstrate that empirical tests concerning this debate can be overturned if the effects of discrete target changes are taken into account. The next section describes such a discreteness adjustment.

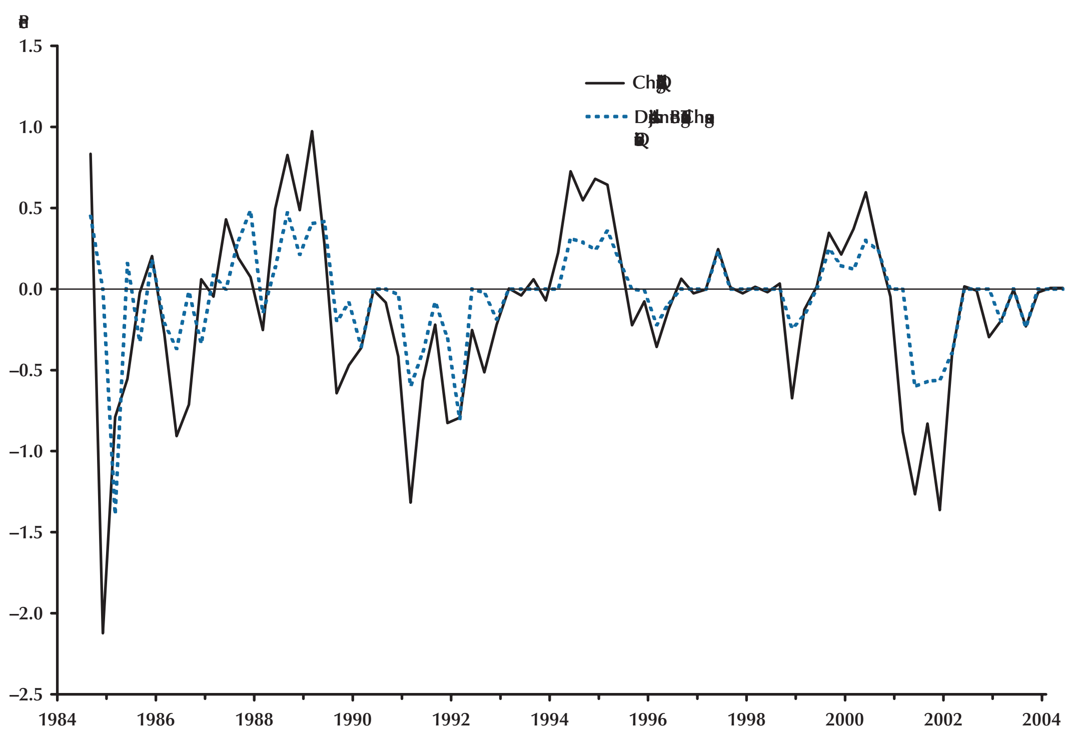
## DISCRETE TARGET CHANGES AND FORECASTS OF THE QUARTERLY AVERAGE

The discreteness adjustment is the one used in Dueker (2002) and assumes that any target change made to the federal funds rate during the quarter is likely to remain in force through the next quarter. In this case, the starting point for this quarter's funds rate is not the previous quarter's average but the target rate that held at the end of the previous quarter. Another way to look at this issue is to note that, if a quarter has $N$ business days and a 50-basis-point increase in the target federal funds rate occurs after $N_j$ business days have elapsed in the quarter, then, other things equal, the effect of such a target change on the next quarter's average, relative to this quarter's average, would be to increase it by $N_j/N \times 50$ basis points above this quarter's average, $\bar{i}_t$. If more than one discrete change takes place within a quarter, then the effect of the target changes on the quarterly average would be

## Figure 1




## Figure 2



(1) $$DDV_{t-1} = \sum_j N_j / N \times \Delta i^T_{j,t-1},$$

where the discrete target changes are denoted $\Delta i^T$ and *DDV* is the discreteness variable first used in Dueker (2002). An equivalent way to present this discreteness adjustment is that it serves as a link between last quarter's average and the target rate at the end of the quarter:

(2) $$i_{t-1} + DDV_{t-1} = i^T_{t-1},$$

where $i^T$ is the end-of-period value of the target federal funds rate and $i$ is the quarterly average.

Figure 1 plots the target federal funds rate along with the quarterly average of the federal funds rate. In the chart, one can see that target changes can precede some upward and downward shifts in the quarterly average. Figure 2 makes this pattern even more apparent: It plots the changes in the quarterly average, $i_t - i_{t-1}$, with the discreteness adjustment, $DDV_{t-1} = i^T_{t-1} - i_{t-1}$. It is clear from the close correspondence in Figure 2 that $DDV_{t-1}$ will be a relatively powerful predictor of changes in the quarterly average of the federal funds rate, based on target changes that took place in the previous quarter. Indeed this conjecture proves to be the case in the empirical results presented in the next section.

## ESTIMATION RESULTS FOR LINEAR TAYLOR RULES WITH RATE SMOOTHING

English, Nelson, and Sack (2003) observed that the hypotheses of interest rate smoothing and persistent omitted factors can be nested in one specification of a policy equation. Using their notation, let $i$, $\pi$, and $y$ denote, respectively, the interest rate, the inflation rate, and the output gap. As discussed above, the interest rate used as the monetary policy instrument is the quarterly average of the federal funds rate; the inflation rate is the most recent four-quarter change in the chain-weighted personal consumption expenditures price index; the output gap is the percentage difference between chain-weighted real gross domestic product (GDP) and the potential GDP measure from the Congressional Budget Office. The sample period is from 1984:Q2 to 2004:Q2 and coincides with the period for which a well-accepted series for the target federal funds rate exists.

For this illustration of the effects of discrete target changes on the quarterly average of the federal funds rate, the basic policy equation is a contemporaneous Taylor rule, whereby monetary policy responds to the current values of the inflation rate and the output gap. (Alternative forward-looking Taylor rules can make use of measures of expected inflation.) With the two behavioral assumptions appended, the following three equations describe the policy rule in its entirety:

$$\hat{i}_t = b_0 + b_\pi \pi_t + b_y y_t \qquad \text{Taylor rule}$$

(3) $$i_t = (1-\lambda)\hat{i}_t + \lambda i_{t-1} + v_t \qquad \text{Rate smoothing}$$

$$v_t = \rho v_{t-1} + \varepsilon_t, \qquad \text{Autogressive errors}$$

where $\hat{i}$ represents the Taylor rule–implied level of the federal funds rate in the absence of interest rate smoothing and policy concerns other than inflation and the output gap; $\lambda$ is the interest rate smoothing parameter under the assumption that the rate policymakers inherit from the past is $i_{t-1}$ (which we can also call the reference rate for the purposes of interest rate smoothing); and $\rho$ measures the persistence of omitted factors that also concern monetary policymakers. For the side of the debate that believes that monetary policymakers smooth interest rates purposefully, $\lambda$ would account for the gradual adjustment of the federal funds rate and $\rho$ would be zero. For the opposite side of the debate, $\lambda$ would be zero and the gradual adjustment would be explained by errors due to omitted ancillary policy concerns, such as financial market disturbances, in the form of autoregressive model errors.

The purpose of the interest rate smoothing equation is to assume that monetary policymakers set the rate this period equal to a weighted average of the rate implied by the Taylor rule and the rate inherited from the previous quarter. Following the previous period's target changes, however, the rate inherited from the past ought to be the end-of-period target level, $i^T_{t-1}$, and not $i_{t-1}$, the previous quarter's average. But this hypothesis is testable, as we can nest the two specifications as follows.

With discreteness adjustment, the expression in equation (3) becomes

(4)

$$\hat{i}_t = b_0 + b_\pi \pi_t + b_y y_t \qquad \text{Taylor rule}$$

$$i_t = (1-\lambda)\hat{i}_t + \lambda\left[i_{t-1} + DDV_{t-1}\right] + \delta DDV_{t-1} + v_t$$

Discreteness-adjusted rate smoothing

$$v_t = \rho v_{t-1} + \varepsilon_t, \qquad \text{Autoregressive errors}$$

## Table 1

### Calculation of the Discreteness Adjustment

| | Days in quarter | Days within quarter when target changed | | | | | Discreteness adjustment for following quarter |
|---|---|---|---|---|---|---|---|
| **1990:Q4** | 66 | 12 | 33 | 50 | 58 | | |
| Rate change | | –0.25 | –0.25 | –0.25 | –0.25 | | |
| | | (20/66)*(–0.25) + | (32/66)*(–0.25) + | (49/66)*(–0.25) + | (57/66)*(–0.25) | = | –0.5985 |
| **1994:Q2** | 65 | 12 | 33 | | | | |
| Rate change | | 0.25 | 0.50 | — | — | | |
| | | (11/65)*(0.25) + | (32/65)*(0.50) | | | = | 0.2885 |
| **2001:Q1** | 65 | 3 | 23 | 57 | | | |
| Rate change | | –0.50 | –0.50 | –0.50 | — | | |
| | | (2/65)*(–0.50) + | (22/65)*(–0.50) + | (56/65)*(–0.50) | | = | –0.6154 |

where the rate inherited from the previous quarter is the end-of-period target level, $i^T_{t-1} = i_{t-1} + DDV_{t-1}$, if $\delta = 0$ and it equals the previous quarter's average if $\delta = -\lambda$.

English, Nelson, and Sack (2003) combine the three expressions from equation (3) into one equation that describes the changes in the federal funds rate:

(5)

$$\Delta i_t = (1-\lambda)\Delta\hat{i}_t + \lambda\Delta i_{t-1} + (\rho - 1)\left[i_{t-1} - (1-\lambda)\hat{i}_{t-1} - \lambda i_{t-2}\right] + \varepsilon_t$$
$$\varepsilon_t \sim N\left(0, \sigma^2\right),$$

where $\hat{i}$ is the Taylor rule–implied level of the federal funds rate absent any interest rate smoothing or autoregressive errors due to ancillary policy concerns.

With the discreteness adjustment, the combined expression is as follows:

(6)

$$\Delta i_t = (1-\lambda)\Delta\hat{i}_t + \lambda\Delta i_{t-1} + (\lambda + \delta)\Delta DDV_{t-1}$$
$$+(\rho - 1)[i_{t-1} - (1-\lambda)\hat{i}_{t-1} - \lambda i_{t-2} - (\lambda + \delta) DDV_{t-2}] + \varepsilon_t.$$

A key feature of the specification in equations (5) and (6) is that it does not impose either hypothesis ($\lambda = 0$ or $\rho = 0$). Judd and Rudebusch (1998) called $\Delta i_{t-1}$ a term that captured "momentum" from the previous period's funds rate change. The purpose of the discreteness adjustment, however, is to provide an accurate reflection of the momentum implied by the previous period's discrete target changes, which frees $\Delta i_{t-1}$ from having to play this role.

Nonlinear least-squares estimates for equation (5) are shown in the first column of Table 2. The results without the discreteness adjustment, *DDV*, concur with English, Nelson, and Sack (2003) in that both $\lambda$ and $\rho$ are significantly greater than zero, and the Taylor rule still seems operative, given significant coefficients on $b_\pi$ and $b_y$. A well-known stability property of Taylor rules is that the coefficient on inflation must be greater than 1 and the estimate of $b_\pi = 1.25$ from equation (5) meets this criterion even if its standard error is 0.50. In most cases, the analysis often stops at this point, with a standard error of the regression of 33 basis points per quarter.

Our discussion of the discreteness adjustment leads us to believe, however, that these results might change if the empirical model incorporated information regarding target changes in the previous quarter. Equation (4) suggests that when $\delta = 0$, the starting point for interest rate smoothing is the end-of-period target rate, rather than the most recent quarterly average. If it is the quarterly average, on the other hand, then a value of $\delta = -\lambda$ would remove the discreteness adjustment, *DDV*, from equations (4) and (6). The second column of Table 2 shows estimates of equation (6) with an estimate of $\delta$. Put in the context of equation (2), this value of $\delta$ implies that the reference rate for interest smoothing is $i_{t-1} + 1.24(i^T_{t-1} - i_{t-1})$.This coefficient is very close to the value of 1.21 that Dueker (2002) found on the same discreteness-adjustment variable in a vector autoregression. In both cases, however, the coefficient $\delta$ is not significantly different from zero, which suggests that the reference rate for interest rate smoothing is the end-of-period target rate, $i^T_{t-1}$, and not the most recent quarterly average, $t_{t-1}$. Accordingly, the last column in Table 2 shows the estimates for equation (6) with $\delta$ set to zero and finds that the standard error of the regression is essentially unchanged from when $\delta = 0.24$ (middle column of

**Table 2**

**Taylor Rule Policy Equations with and without Discreteness Adjustment, 1984:Q2–2004:Q2**

| Variable | Coefficient | No discreteness | Discreteness | |
|---|---|---|---|---|
| Intercept | $b_0$ | 2.28<br>(1.24) | 1.12<br>(2.42) | 1.24<br>(1.85) |
| Inflation | $b_\pi$ | 1.248<br>(0.498) | 1.971<br>(0.937) | 1.846<br>(0.706) |
| Output gap | $b_y$ | 0.853<br>(0.354) | 0.948<br>(0.610) | 1.073<br>(0.486) |
| Rate smoothing | $\lambda$ | 0.719<br>(0.108) | 0.951<br>(0.035) | 0.919<br>(0.041) |
| Autoregressive errors | $\rho$ | 0.769<br>(0.134) | 0.281<br>(0.144) | 0.438<br>(0.118) |
| Inherited rate | $\delta$ | — | 0.241<br>(0.182) | — |
| S.E. | $\sigma$ | 0.333 | 0.275 | 0.275 |
| $\bar{R}^2$ | | 0.502 | 0.660 | 0.660 |

NOTE: Standard errors are in parentheses.

Table 2). In contrast, the standard error of the regression in Table 2 is 21 percent higher when the discreteness adjustment is omitted. Based on this estimate, we set $\delta = 0$ in all subsequent model specifications.

In terms of Taylor rule coefficients, interest rate smoothing parameters, and autoregressive errors, the estimates with and without the discreteness adjustment are also different. The point estimates of the inflation and output gap response coefficients are higher with the discreteness adjustment, although their standard errors are relatively large. In the last column of Table 2, the estimated values of $b_\pi$ and $b_y$ are 1.85 and 1.07, respectively. In addition, the estimated value of $\lambda$ goes up and $\rho$ goes down with the discreteness adjustment. Instead of being roughly equal at about 0.75 without the discreteness adjustment, $\lambda = 0.92$ and $\rho = 0.44$ with the discreteness adjustment (last column of Table 2).

Two caveats, however, hinder us from interpreting $\lambda = 0.92$ as direct evidence of interest rate smoothing. First, this estimate covers all quarters and thereby mixes the roughly 40 percent of all quarters when the target federal funds rate did not change with the 60 percent when the target did change. Second, we need to consider the fact that monetary policymakers would not move the target funds rate to the Taylor rule–implied level at the beginning of each quarter; instead they could act slowly but, by the end of the period, set the target rate, $i^T$, equal to the Taylor rate, $\hat{i}$. As an extreme example, suppose that the target is always unchanged until two-thirds of the way through each quarter, whereupon it is set equal to the Taylor rate, $\hat{i}$. This timing alone would result in a value of $\lambda = 0.66$ to match the quarterly average:

$$i_t = 0.333\hat{i}_t + 0.667 i^T_{t-1}.$$

Firm evidence of interest rate smoothing requires that $\hat{i}_t - i^T_t$ show persistence beyond any found in the autoregressive errors. To study the persistence of $\hat{i}_t - i^T_t$, however, we would like the estimate of $\hat{i}_t$ to come from a model that recognizes that policymakers do not change the target funds rate every quarter and, hence, the standard deviation of the residual, denoted $\sigma$, will sometimes be much lower than the 28 basis points shown in Table 2.

One way to separate the target change/no target change regimes in a predictive model is to make $\lambda$ and the standard deviation, $\sigma$, subject to regime switching. We explore such a nonlinear Taylor rule model of monetary policy in the next section.

## ESTIMATION RESULTS FOR NONLINEAR TAYLOR RULES WITH RATE SMOOTHING

A clean test for interest rate smoothing—in the form of persistence in the gap between the Taylor rule rate and the end-of-period target, $\hat{i}_t - i^T_t$—would

## Table 3

**Markov-Switching Model with Switching in Taylor Rule Intercept and Smoothing, 1984:Q2–2004:Q2**

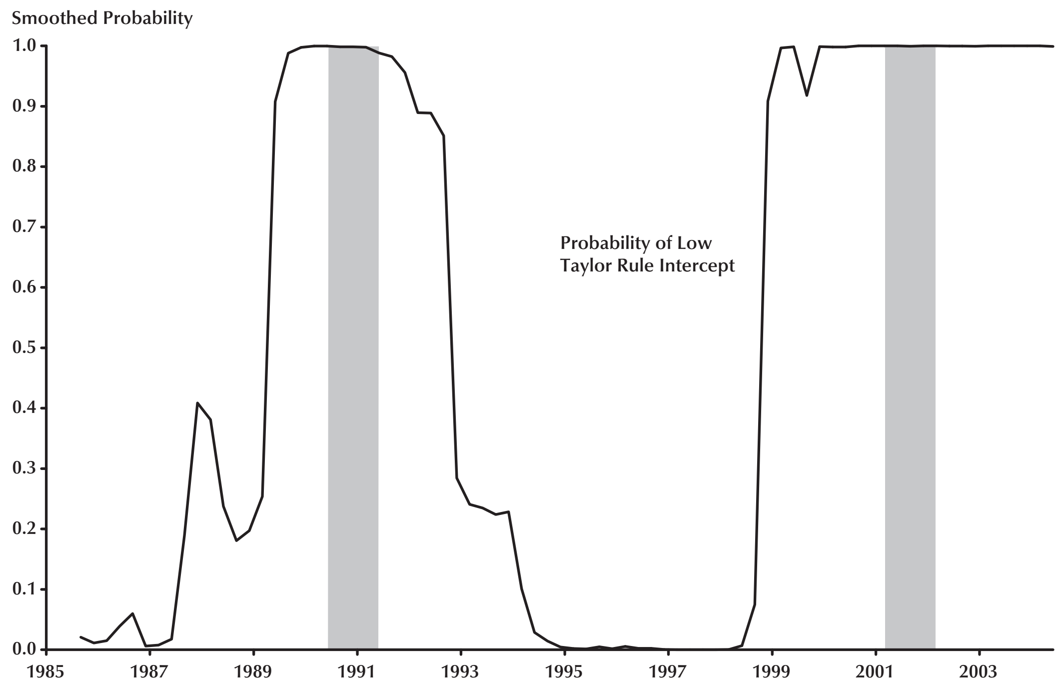
| Variable | Coefficient | No discreteness | Discreteness |
|---|---|---|---|
| Intercepts | $b_{0,\,S1=1}$ | –0.898<br>(0.819) | 0.581<br>(0.421) |
| | $b_{0,\,S1=2}$ | 2.48<br>(0.657) | 4.35<br>(0.480) |
| Inflation | $b_\pi$ | 1.927<br>(0.239) | 1.721<br>(0.167) |
| Output gap | $b_y$ | 0.969<br>(0.164) | 1.11<br>(0.094) |
| Rate smoothing | $\lambda_{S2=1}$ | 1.0 | 0.980<br>(0.003) |
| Rate smoothing | $\lambda_{S2=2}$ | 0.717<br>(0.045) | 0.888<br>(0.033) |
| Autoregressive errors | $\rho$ | 0.280<br>(0.030) | 0.00<br>(0.012) |
| Transition probabilities | $p_1$ | 0.955<br>(0.034) | 0.947<br>(0.043) |
| Transition probabilities | $q_1$ | 0.951<br>(0.038) | 0.943<br>(0.049) |
| Transition probabilities | $p_2$ | 0.473<br>(0.137) | 0.636<br>(0.122) |
| Transition probabilities | $q_2$ | 0.711<br>(0.087) | 0.763<br>(0.077) |
| S.E.E. | $\sigma_{S2=1}$ | 0.057<br>(0.010) | 0.014<br>(0.004) |
| S.E.E. | $\sigma_{S2=2}$ | 0.271<br>(0.030) | 0.303<br>(0.042) |

NOTE: Standard errors are in parentheses.

use an estimate of the Taylor rule rate from a model that had two key attributes: First, the model would not use data from quarters when policymakers did not change the target federal funds rate to estimate Taylor rule coefficients; second, the model would not have autocorrelated errors. The first attribute is important because we want a model that fits the data in quarters where the target does not change with the common-sense specification, $\Delta i_t = DDV_{t-1} = i^T_{t-1} - i_{t-1}$, which requires in equation (6) that $\lambda = 1$, $\rho = 0$, and $\delta = 0$ for those non-target-change observations. If the second attribute, $\rho = 0$, holds for all observations, then the end-of-period target ought to equal the Taylor rule rate under the hypothesis of no rate smoothing.

To find a model specification that has these two desirable attributes, we introduce Markov switching to two of the model parameters, $\lambda$ and $b_0$, the Taylor rule intercept. The intent is to allow complete smoothing ($\lambda_1 \approx 1$) in one of the states, which ought to coincide fairly well with the periods when the target does not change. The value of $\lambda$ in the other state, $\lambda_2$, could take on a lower value. The objective behind regime switching in the Taylor rule intercept, $b_0$, is to lower or eliminate autocorrelation in the model errors. In a Taylor rule, the intercept $b_0 = r^* - (1 - b_\pi)\pi^*$, where $r^*$ is the equilibrium short-term real interest rate and $\pi^*$ is the inflation target. Because temporary changes in some combination of $r^*$ and $\pi^*$ could occur across the business cycle or in periods

## Figure 3




NOTE: Shaded areas are recessions (as determined by the National Bureau of Economic Research).

of financial market upset, it seems natural to investigate whether variation in $b_0$ could remove some or all of the autocorrelation in the errors.

We allow the regime switching in these two parameters to take place independently through two separate state variables, $S1$ and $S2$. Thus, the Taylor rule rate with regime switching is

$$\hat{i}_t = b_{0,S1_t} + b_\pi \pi_t + b_y y_t \,, \quad \text{Taylor rule} \tag{7}$$

where $S1_t = 1{,}2$ is an unobserved state variable and the transition probabilities are denoted $p_1 = \Pr(S1_t = 1 | S1_{t-1} = 1)$ and $q_1 = \Pr(S1_t = 2 | S1_{t-1} = 2)$.

The rate-smoothing equation with regime switching is

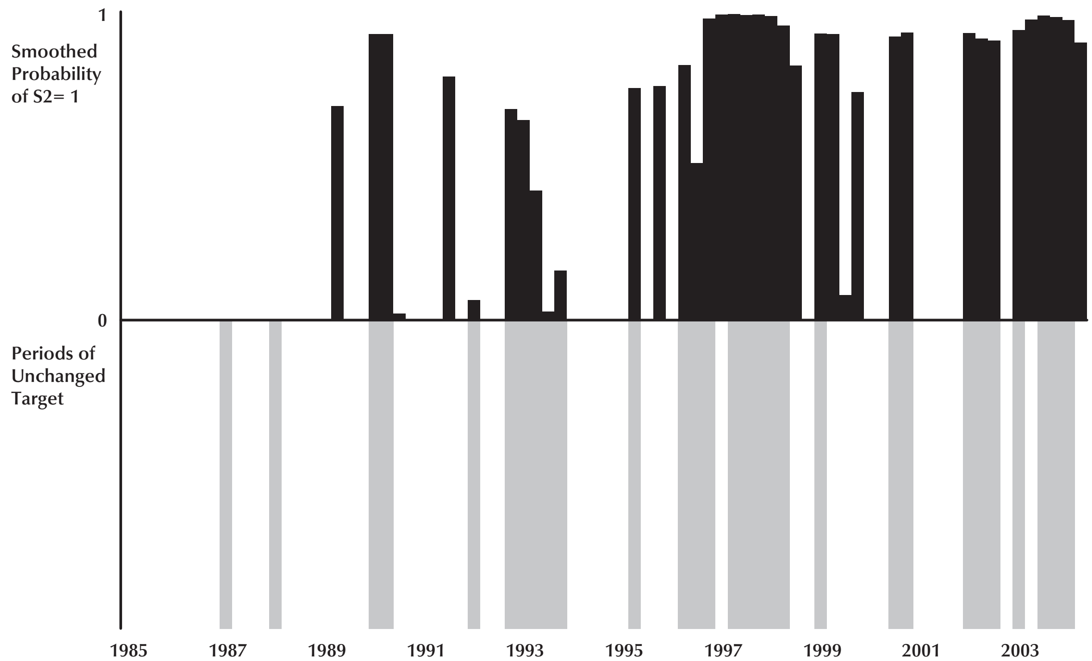
$$i_t = (1 - \lambda_{S2_t})\hat{i}_t + \lambda_{S2_t}(i_{t-1} + DDV_{t-1}) + \sigma_{S2_t} e_t \,, \tag{8}$$

where we also allow the variance to depend on the state variable because we expect much lower variance in the state where $\lambda \approx 1$. For the second state variable, $S2$, we report parameter estimates for both fixed transition probabilities and time-varying transition probabilities. The fixed transition probabilities are denoted $p_2 = \Pr(S2_t = 1 | S2_{t-1} = 1)$ and $q_2 = \Pr(S2_t = 2 | S2_{t-1} = 2)$.

Parameter estimates for the model with fixed transition probabilities are in Table 3. Figure 3 shows the smoothed probability of the low Taylor rule intercept ($S1 = 1$) from the model with the discreteness adjustment. The periods when the Taylor rule intercept is low coincide roughly with periods when interest rates experience cyclical fluctuations around recessions, which are shaded in the chart. Importantly, the model with the discreteness adjustment is able to separate periods when the target changed from periods when it did not, because the variance parameters are farther apart for that model. The model with the discreteness adjustment is also able to eliminate the autocorrelation in the errors, whereas the model without the discreteness adjustment still has significantly autocorrelated errors, with $\rho = 0.28$. Without constraining $\lambda$, it takes a value very close to 1.0 when $S2 = 1$. Even when it equals 0.98 in the model with the discreteness adjustment, the economic effect of this difference in terms of basis points is negligible. In other words, the model imputes essentially zero input from the Taylor rule rate when $\lambda = 0.98$.

Figure 4 shows how well the smoothed probability of $S2 = 1$ matches periods when the target federal funds rate did not change for the model with the discreteness adjustment and the parameter values

**Figure 4**




from Table 3. The correspondence is quite close, suggesting that the Taylor response coefficients are not attempting to explain much about the quarters when policymakers left the target rate unchanged, because $\lambda$ is very close to 1.0 in that state.

Despite these apparently strong results, constant transition probabilities are not completely satisfactory for switching in the parameter $\lambda$. We would expect that policymakers would respond systematically to economic developments when deciding in which periods to leave the target unchanged and set $\lambda$ to 1. In reality, these no-change periods have an endogenous component and are not solely the result of coin flips. One natural variable to use to predict whether a target change will occur is $Z_t = abs(\hat{i}_t - i^T_{t-1})$, the gap between the Taylor rule rate and the most recent end-of-period target federal funds rate. If the size of this gap is large in absolute value, then we would expect that a target change and the regime where $\lambda \approx 1$ are more likely. With this explanatory variable, we parameterize the time-varying transition probabilities for $S2$ as

(9)

$$\Pr(S2_t = 1 \mid S2_{t-1} = 1) = \exp(c_0 + c_1 Z_t) / [1 + \exp(c_0 + c_1 Z_t)]$$
$$\Pr(S2_t = 2 \mid S2_{t-1} = 2) = \exp(d_0 + d_1 Z_t) / [1 + \exp(d_0 + d_1 Z_t)].$$

Because $S2 = 1$ is the state where $\lambda \approx 1$ and the target is less likely to change, we would expect to find $c_1 < 0$ and $d_1 > 0$. These signs would mean that monetary policymakers are more likely to accept feedback from the Taylor rule rate when the gap between the Taylor rule rate and the prevailing target rate, $abs(\hat{i}_t - i^T_{t-1})$, is large.

Parameter estimates for the Markov-switching model with time-varying transition probabilities are in Table 4. The estimates are relatively unchanged from Table 3. The only significant coefficient on $Z_t$ is $c_1 < 0$ in the model without the discreteness adjustment. This coefficient implies that, if $abs(\hat{i}_t - i^T_{t-1})$ is large, then policymakers are likely to switch out of the state where $\lambda \approx 1$ if they had been in that state. In the model with the discreteness adjustment, $d_1$ has a point estimate above zero, as expected, but it is not statistically significant. Thus, although we have presented a framework for predicting when monetary policymakers are likely to keep the federal funds target unchanged, we have not yet identified a significant explanatory variable for the time-varying transition probabilities. For this reason, we report estimates from the fixed transition probability model to examine persistence in the gap between the Taylor rule rate and the end-of-period federal funds target rate, $\hat{i}_t - i^T_t$. Because these regimes are endogenous, further research on the process governing target rate changes is needed. In this vein,

**Table 4**

**Markov-Switching Model with Time-Varying Transition Probabilities on the Smoothing Parameter, 1984:Q2–2004:Q2**

| Variable | Coefficient | No discreteness | Discreteness |
|---|---|---|---|
| Intercepts | $b_{0,\,S1=1}$ | –0.818<br>(1.17) | 0.579<br>(0.393) |
| | $b_{0,\,S1=2}$ | 2.46<br>(0.488) | 4.91<br>(0.697) |
| Inflation | $b_{\pi}$ | 1.877<br>(0.276) | 1.728<br>(0.161) |
| Output gap | $b_{y}$ | 1.049<br>(0.244) | 1.070<br>(0.092) |
| Rate smoothing | $\lambda_{S2=1}$ | 0.999<br>(0.008) | 0.986<br>(0.003) |
| Rate smoothing | $\lambda_{S2=2}$ | 0.738<br>(0.070) | 0.890<br>(0.023) |
| Autoregressive errors | $\rho$ | 0.294<br>(0.026) | 0.006<br>(0.010) |
| Transition probabilities | $p_1$ | 0.974<br>(0.023) | 0.943<br>(0.035) |
| Transition probabilities | $q_1$ | 0.933<br>(0.025) | 0.835<br>(0.107) |
| Transition probabilities | $c_0$ | 433.8<br>(75.7) | 0.261<br>(1.00) |
| Transition probabilities | $c_1$ | –548.8<br>(145.6) | 0.355<br>(0.633) |
| Transition probabilities | $d_0$ | 1.11<br>(1.00) | 0.427<br>(0.819) |
| Transition probabilities | $d_1$ | –0.26<br>(0.77) | 1.236<br>(1.144) |
| S.E.E. | $\sigma$ | 0.195<br>(0.018) | 0.245<br>(0.070) |
| S.E.E. | $\sigma_{S2=1}$ | 0.052<br>(0.009) | 0.267<br>(0.029) |

NOTE: Standard errors are in parentheses.

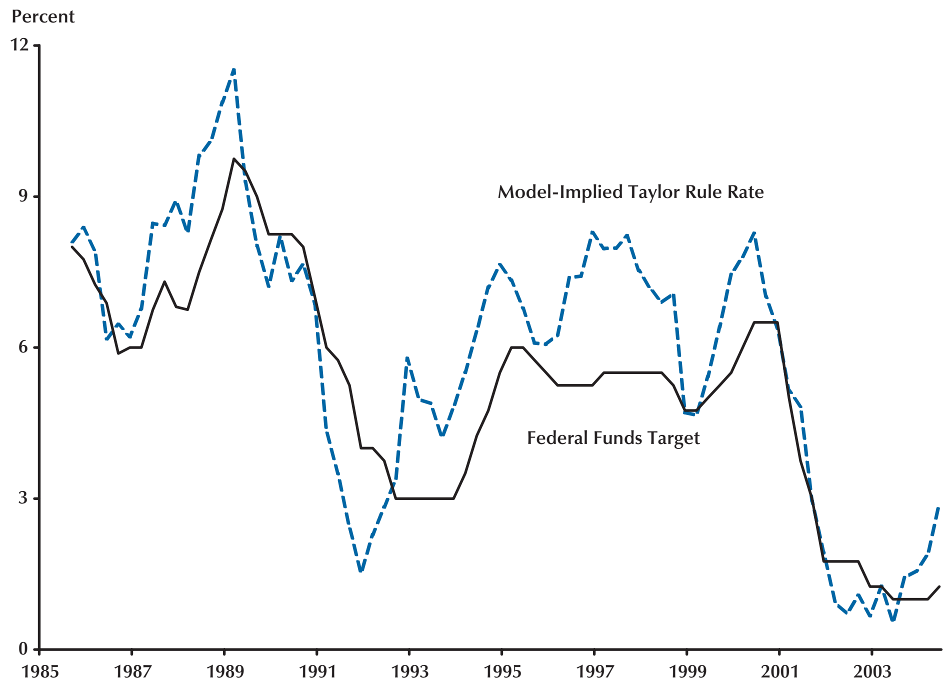
Hamilton and Jorda (2002) present an autoregressive conditional hazard model of the target federal funds rate. Similarly, a dynamic ordered probit model, of the type that Dueker (1999) estimated, of changes in the bank prime rate could be applied to target changes.

## A MEASURE OF INTEREST RATE SMOOTHING

As discussed above, only models in which the errors are not autocorrelated, $\rho = 0$, imply that the end-of-period target ought to equal the Taylor rule rate under the hypothesis of no rate smoothing. A comparison of Tables 2, 3, and 4 shows that only the Markov-switching models with the discreteness adjustment eliminate the autocorrelation in the model errors. Consequently, a direct measure of the degree of interest rate smoothing is the correlogram of $\hat{i}_t - i_t^T$ from these two models.

However, because the value of the likelihood function barely changes between Tables 3 and 4 for the model with the discreteness adjustment, we

**Figure 5**




concentrate on the results from Table 3, the specification with fixed transition probabilities. Figure 5 shows the Taylor rule rate implied by the Table 4 estimates with the end-of-period target. In general, the Taylor rule rate leads the target when the target rises and falls. It is remarkable, therefore, that the target, on its descent between 2001 and 2003, did not lag the Taylor rule rate. Monetary policymakers apparently were not smoothing the interest rate as the economy went into recession in 2001. Table 5's correlogram of the difference between the model-implied Taylor rule rate and the target federal funds rate shows that Federal Reserve policymakers close the gap within about six quarters on average. Thus, the degree of interest rate smoothing is considerable but has a relatively short horizon.

**Table 5**

**Correlogram of the Gap Between the Federal Funds Target Rate and the Markov-Switching Taylor Rule Rate with Discreteness Adjustment, 1984:Q2–2004:Q2**

| Lag | Autocorrelation |
|---|---|
| 1 | 0.826 |
| 2 | 0.655 |
| 3 | 0.447 |
| 4 | 0.269 |
| 5 | 0.167 |
| 6 | 0.079 |
| 7 | 0.054 |
| 8 | –0.036 |
| 9 | –0.114 |
| 10 | –0.188 |

## SUMMARY AND CONCLUSIONS

This article points out that discrete changes to the target federal funds rate are a clear source of predictable change in the monthly or quarterly average of the daily federal funds rates. Figure 2 suggests that the adjustment for the discrete target changes accounts for what is perhaps a surprising amount of the sample variance of the changes in the quarterly average. Thus, the discreteness adjustment carries the potential to overturn estimation results that involve the monthly or quarterly average of the federal funds rate. We present such an example by examining the debate concerning interest rate smoothing in policy rules. Without the discreteness adjustment, estimation results suggest that interest rate smoothing is not the only source of gradualism in interest rate changes. With the discreteness adjustment, however, the empirical results strongly favor interest rate smoothing as the source of gradualism in federal funds rate changes. We also show that the discreteness adjustment affects empirical results concerning the policy equations even in relatively rich models that include regime switching.

The Markov-switching framework we present is adept at separating the regime where policymakers change the target from the regime where they do not. This framework can employ explanatory variables in the transition probabilities to predict these regimes ahead of time. Future work can concentrate on studying the determinants of the target change decisions of policymakers.

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