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NEW EVIDENCE ON THE FIRM SIZE EFFECTS IN US MONETARY POLICY TRANSMISSION

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Abstract
This paper employs US state level data on manufacturing and non-manufacturing industries to present new evidence on the transmission of US interest rate shocks. Part one of our study analyzes the interest rate sensitivity of industry earnings over the period 1958-2000/01. The vector autoregressive evidence points to differences in the interest rate sensitivity of industries and, hence, to the existence of an industry channel of monetary transmission. Building on these results, the second part investigates whether the industry characteristics business size and capital intensity can explain the cross-industry heterogeneity of monetary policy effects. We find that the conclusions strongly depend on the treatment of the mining industry. Including a dummy variable for the mining industry significantly reduces the explanatory power of business size but brings to the fore the effect of capital intensity.

Keywords: Monetary transmission, industry effects, regional effects, business size

JEL Classification: E50, E52

I. Introduction

The United States and the Euro area constitute the most prominent monetary unions of our time. In the years preceding the formation of the European Economic and Monetary Union (EMU), the US were frequently chosen as a natural yardstick to assess the adoption of the common currency. The usefulness of the US as benchmark country arises from two sources. Firstly, similar to the Euro area, the United States comprise a large set of heterogeneous regions whose economic performance is influenced by the actions of a single central bank. Secondly, the US report high quality data on the structural characteristics of its regions. Regional disaggregated data are a prerequisite for the identification of factors that determine the process of monetary transmission and that may cause cross-region differences in the effects of monetary policy. Since disaggregated data are not available for a comprehensive sample of Euro-zone regions, investigations of the transmission of US monetary policy may provide insights into the regional effects of the monetary policy of the European Central Bank (ECB).

A large theoretical and empirical literature stresses asset prices, wealth, exchange rates, financial structure and the interest rate sensitivity of industries, firms, and banks as mechanisms that propagate and amplify the effects of monetary policy on economic activity. Many empirical studies point to the role of small-sized businesses in the monetary transmission mechanism. The statistical significance of a business size variable is usually taken as evidence of the importance of credit market imperfections. In this way, the possible interaction between business size and the cyclical sensitivity of industries is neglected. However, as Eichenbaum (1994) notes, the potential interdependence of business size and industry complicates the identification of factors associated with each channel of monetary transmission. For example, if business size would be correlated with the cyclical behavior of industries, the neglect of industry effects in empirical work could explain the significance of business size, even in absence of any credit market imperfections.

Motivated by Eichenbaum (1994), this paper aims to analyze the industry effects of monetary policy in more detail. To this end we first analyze the interest rate sensitivity of US industry earnings over the period 1958-2000/01. Having documented differences in the interest rate sensitivity of industries, we next investigate whether the industry characteristics business size and capital intensity can explain the cross-industry heterogeneity of monetary policy effects. This will allow us to assess the nature of the interrelationship between business size and the cyclical sensitivity of industries. Does business size indeed pick up industry effects, as Eichenbaum (1994) suggests, or is there an independent effect of business size? We also pay attention to the capital intensity of production as an additional determinant of monetary policy effectiveness. In contrast to business size, this industry characteristic is more closely associated with the interest rate channel of monetary policy than with the credit channel.

The remainder of this paper is structured as follows. Section II reviews the role of interest rates and credit market conditions as potential sources of cross-region differences in the effects of monetary policy. Section III reports differences in the interest rate sensitivity of economic activity by industry sector and by US state. Building on these time-series estimates, Section IV discusses the cross-section analysis linking the interest rate sensitivity of industries to the size distribution of businesses and to their degree of capital intensity. Section V concludes.

II. Transmission Mechanisms of Monetary Policy

The effectiveness of monetary policy is determined by a range of transmission channels. Regional differences in the relative strength of these channels may explain regional dissimilarities in the effects of monetary policy. This section reviews the transmission of monetary policy through the interest rate and credit channels. In most empirical work the factors we focus on in this study – industry effects, business size and capital intensity – are associated with one of these two channels.[1]

According to the interest rate channel, market interest rates constitute the main avenue through which monetary policy affects economic activity.[2] When prices are sticky changes in nominal interest rates will have real short-run effects. Following a monetary tightening, the real effects arise from an increase in the user cost of capital that reduces the degree of capital investment and durable goods consumption. This lowers output, especially in industries producing investment goods and durable consumption goods. These industries also tend to have a high capital intensity. Therefore the interest rate channel is sometimes also referred to as the industry channel. The interest rate channel attributes regional differences in monetary policy effects to regional dissimilarities in the importance of capital-intensive and interest-sensitive industries and, hence, to regional differences in economic structures. Previous empirical research has shown that regions with a large share of capital-intensive industries like manufacturing, mining, construction and transportation are likely to respond more strongly to interest rate shocks than regions with less capital-intensive industries like services and the public sector.[3]

The credit view goes beyond the concept of sticky prices by also considering frictions in financial markets. Depending on whether these imperfections are deemed more important at the level of banks or firms, a distinction is made between the narrow and broad credit channel. Both credit channels require imperfect substitution between external and internal funds caused by information asymmetries in financial markets.[4] The narrow credit view, also known as the bank lending channel, emphasizes the influence of monetary policy actions on bank lending through their effect on bank reserves.[5] At the core of this channel is the practice of banks to finance loans in part with liabilities that are subject to reserve requirements. Following a monetary tightening, the level of bank reserves declines due to the consequent sale of securities. In the presence of credit market imperfections, banks cannot offset the fall in reserves with alternative forms of non-reservable finance, so their ability and willingness to supply loans deteriorates. If firms or households are bank-dependent and lack substitutes for bank loans, their cutback in bank lending may curtail aggregate spending. The broad credit view, also

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[1] See, e.g., Bernanke and Gertler (1995), Christiano, Eichenbaum, and Evans (1998), Dornbusch, Favero, and Giavazzi (1998), Kieler and Saarenheimo (1998), and De Bondt (1998) for surveys.

[2] See Hubbard (1994), Kashyap and Stein (1994), Kakes, Sturm, and Maier (1999), Mojon (2000), and Kuttner and Mosser (2002) for a detailed discussion of the traditional interest rate channel.

[3] Ganley and Salmon (1997) provide evidence of cross-industry differences in interest rate sensitivity for the United Kingdom. Evidence of regional disparities in the strength of the interest rate channel is provided by Carlino and DeFina (1998, 1999a, 1999b, 2000), Hayo and Uhlenbrock (2000), Arnold (2000), Dedola and Lippi (2000), Peersman and Smets (2002), and Arnold and Vrugt (2004).

[4] See Bernanke and Blinder (1988), Bernanke and Mihov (1995), Bernanke, Gertler, and Gilchrist (1999), and Gertler and Gilchrist (1993, 1994).

[5] See Bernanke and Blinder (1988), Gertler and Gilchrist (1993), Kashyap, Stein, and Wilcox (1993) for a discussion of the bank reserve channel. See Romer and Romer (1990), Kashyap and Stein (1997b), and Van den Heuvel (2002a, 2002b) for a criticism on the significance of the bank lending channel.

known as the balance sheet channel, works through the influence of monetary policy on the balance sheet of firms. Following a monetary tightening, the balance sheets will deteriorate. Because of asymmetric information problems in credit markets, the risk premium on external funds increases. Reflecting firms' lower creditworthiness, the higher risk premium comes along with a cutback in lending to debtors by financial institutions. Similar to the bank lending channel, the decline in the supply of external funds will reduce investment spending.

Regional differences in the strength of the credit channel reflect disparities in both the financial and the economic structure.[6] The narrow credit view focuses on differences in the size distribution of banks. Regions with a relatively large share of small banks would respond more strongly to changes in monetary policy than regions with a large proportion of large and well-capitalized banks.[7] The broad credit view links regional differences in monetary transmission to differences in the size distribution of firms. Information asymmetries and a lower level of net worth increase the bank dependence of small firms relative to large businesses and, hence, their susceptibility to fluctuations in bank loan supply.[8] So regions with a high share of small firms should respond more strongly to monetary policy shocks.

According to Eichenbaum (1994), firm size is an appropriate measure for the credit channel only if size and industry are independent. If this condition doesn't hold, evidence in favor of a credit channel – based on a significant firm size effect- will be biased in estimates that do not control for industry effects. Gertler and Gilchrist (1994) and Ehrmann (2004) try to solve this problem in the following ways. Gertler and Gilchrist (1994) compute the ratio of durable sales over total manufacturing sales for five size classes. The variable is introduced to capture differences in the cyclicality of durable and nondurable goods industries. Finding equal ratios for the sampled size categories, they conclude that the size distribution is unrelated to industry. Ehrmann (2004) compares the distribution of firm size across 27 sub-sectors of the German manufacturing industry. Because all size categories are "present" in almost all sub-sectors, he decides not to model the interaction between business size and industry. Yet in our view neither Gertler and Gilchrist (1994) nor Ehrmann (2004) succeed in satisfactorily solving the independence problem. The industry classicification in Gertler and Gilchrist (1994) lacks detail. Regarding Ehrmann's (2004) solution: even the presence of all size categories in every sub-sector doesn't exclude the possibility of interdependence. Arnold and Vrugt (2004) formally test the independence assumption by identifying the relative contribution of regions and industries to the variation in business size for German data. Their results show that industries are the main source of variation in business size, suggesting that business size and industry are related. Motivated by their findings on the independence tests, Gertler and Gilchrist (1994) and Ehrmann (2004) test for the existence of a credit channel excluding industry effects, whereas Arnold and Vrugt (2004) include industry dummy variables. The first two studies subsequently report evidence in favor of a credit

[6] See Gertler and Gilchrist (1994), Oliner and Rudebusch (1996), Ganley and Salmon (1997), De Bondt (2000), Dedola and Lippi (2000), and Ehrmann (2004) for studies that lend support to the operation of a balance sheet channel. See Carlino and DeFina (1998, 1999a, 1999b, 2000) and Arnold and Vrugt (2004) for evidence against the broad credit channel.

[7] See Kashyap and Stein (1997a) and Angeloni, Kashyap, Mojon, and Terlizzese (2002) for evidence in favor of a bank lending channel. Favero, Giavazzi, and Flabbi (1999) and Kakes, Sturm, and Maier (1999) present results that do not lend support to the relevance of banking size as monetary transmission mechanism.

[8] See also Gertler and Gilchrist (1993), Oliner and Rudebusch (1996), Kashyap and Stein (1994, 1997a) for a discussion of differential regional effects.

channel, while the third study provides counter-evidence. Apparently, controlling for industry effects can strongly affect the empirical outcomes.

III. The Industry Effects of Monetary Policy

This study explores the relevance of the industry channel by building on the estimation framework of Carlino and DeFina (1998) and Arnold (2000). Whereas we use the same estimation framework, we add to the empirical literature by combining the geographical and sectoral dimensions of the earlier studies. In particular, our work resembles Carlino and DeFina (1998) by estimating models for 51 US states, the eight main BEA regions, and the US aggregate. It also follows Arnold (2000) by estimating interest rate sensitivities for a set of industries.

III.1 Empirical Model

In order to examine the short-run and long-run impact of exogenous monetary policy changes on the performance of industries in US regions[9], the time-series analysis involves the estimation of a vector autoregressive system. In line with the study of Carlino and DeFina (1998) and Arnold (2000), the vector of endogenous variables consists of real earnings of industry i in region j ($Y_{i,j,t}$), a measure of energy prices (EP_t) and core consumer prices (CP_t). Energy prices and core consumer prices are included to control for supply shocks and to capture developments in the aggregate price level. Next to these non-policy factors, the federal funds rate (FFR_t) is included as monetary policy instrument. The vector of endogenous variables is thus defined as

$$(1) \qquad Z_{i,j,t} = \left[Y_{i,j,t} \quad CP_t \quad EP_t \quad FFR_t \right]', \qquad \text{with } i = 1,\ldots,13\,,\; j = 1,\ldots,60\,.$$

Throughout the study, monetary policy shocks are approximated by interest rate shocks, which are identified by means of a recursive Choleski-decomposition with the variables ordered as in equation (1). This ordering implies that the interest rate is contemporaneously affected by changes in industry earnings, core consumer prices, and energy prices. These non-policy variables, in turn, respond to a shock in the interest rate only with a lag.[10] Furthermore, each endogenous variable displays a contemporaneous response to its own shocks.

In contrast to earlier research, we express the variables in levels to avoid the exclusion of cointegrating relationships from the vector autoregressive system. This approach is motivated by the results of augmented Dicky-Fuller tests and Phillips-Perron tests. The test statistics typically suggest that the individual time series are integrated of order one. Standard unit root tests are criticized for not being able to discriminate between near-unit root and unit root processes in small samples. We have therefore also determined

[9] The term region equally refers to the US aggregate, a US region, or a US state.
[10] The vector of endogenous variables can also include variables that affect the policy variable only with a lag, but respond contemporaneously to policy shocks. Examples of such variables are monetary aggregates and real exchange rates. Since the estimation results are robust to the inclusion of such variables in the present analysis, they are not further considered.

the unit root properties using the Kwiatkowski-Phillips-Schmidt-Shin test. The results largely confirm the first difference stationarity of the time series.

III.2 Time-Series Data

The VAR specifications model the relationship between earnings in industry i in region j, price measures, and the federal funds rate using annual data. Regarding the regional dimension, estimates are computed for each US state, the main eight regions of the Bureau of Economic Analysis (BEA), and a measure of the US aggregate. Regarding the sectoral dimension, estimates are derived for those industries for which business size data are available. In order to have a benchmark to compare the interest rate sensitivity of industries, impulse-response estimates are also computed for region-specific personal income – a proxy variable of aggregate industry earnings. The appendix contains a detailed description of the data.

Personal income and earnings in industry i in region j are expressed in 1996 prices by means of the US implicit GDP deflator. Besides the indirect incorporation of price developments by deflating nominal industry earnings, the VAR model includes two more measures of prices, i.e., core consumer prices and energy prices. Core consumer prices are approximated by the consumer price index less the effects of food and energy prices. Energy prices are measured by the producer price index for fuels, related products, and power relative to the total producer price index. The monetary policy instrument is approximated by the federal funds rate. The VAR models are computed by using data for the sample period 1958-1997 and 1958-2000/01. Differences in the endpoint of the sample are due to missing values in some industry earnings series for 1998 and 2001. Except for the interest rate, all variables are expressed in logarithms.

Our time-series analysis is subject to two data shortcomings. One concerns the annual data frequency, which limits the detail of our impulse responses. This limitation is caused by a lack of quarterly data of sufficient quality. The second shortcoming is that the short sample for which annual data are available precludes a breakdown of our impulse response estimates in sub-sample periods.

III.3 Empirical Results of the Time-Series Analysis

The empirical results are influenced by the number of lags that are used in the estimation of the VAR model. The present analysis determines the optimal lag length by minimizing the Akaike information criterion. The quality of the estimation results is assessed by testing for serial correlation, normality, and heteroscedasticity in the residuals. Given our interest in the impulse response of industry earnings, the Ljung-Box Q-statistic, Jarque-Bera statistic, and Lagrange multiplier test statistic for heteroscedasticity are only computed for the earnings specification of the VAR system. The results of these residual tests indicate that the error terms are well behaved for almost all cross sections.[11] The dynamic impact of a monetary policy shock on industry performance is summarized by

[11] The Q-statistic is computed at residual lag one, two, and four. To conserve on space, none of the diagnostic test statistics is reported. The results are available on request.

the two-year cumulative impulse response of industry earnings.[12] In order to ascertain the significance of the cumulative impulse response estimates, the impulse response functions of the US aggregate and the US regions are computed with 95 percent analytic asymptotic standard error bands. Since the asymptotic standard error bands are by and large different from zero, we conclude that the VAR models do well in explaining the dynamic response of industry earnings.

Since our time-series analysis is carried out for a large set of industries and regions, complications arise as to the presentation and interpretation of the empirical findings. In order to ensure the readability of the results and to conserve on space, this section only discusses the interest rate responsiveness of industries in the eight BEA regions and in the US as a whole. The analysis of variance reported in Table 1 shows the contribution of industries and regions as source of variation in the interest rate sensitivity of earnings. Formally, the two-way analysis of variance is defined for the hypothesis that the long-run earnings effect of monetary policy is the same across either industries or regions. The entries in Table 1 indicate that this hypothesis can be rejected on the state level and the regional level because of discernible cross-industry and cross-region dissimilarities in the effects of monetary policy. Even though impulse responses differ across both industries and regions, the industry effects appear to be the main source of variation. This conclusion arises from the observation that the F-value for the industry effect is much larger than the F-value for the regional effect. Since differences in the effects of monetary policy are predominantly accounted for by differences in the interest rate sensitivity of industries, this study proceeds by evaluating the long-run earnings response of industries for the US aggregate and the main BEA regions rather than for individual US states.[13]

- Insert Table 1 here -

The analysis of variance points to significant cross-industry differences in the effects of monetary policy. Evaluating the two-year cumulative impulse response estimates in Table 2, negative long-run interest rate effects are reported for all industries except for the government and mining sector. Since the mining industry is supply-shock rather than demand-shock driven, this finding indicates that the energy price variable in the VAR system does not fully capture supply shock effects. There are two possible explanations for this result. Theoretically, the positive response of the mining industry to higher interest rates could be attributed to the opportunity costs of not extracting resources. Empirically, the oil crises in the 1970s stimulated the mining sector through their positive effect on the demand for US oil, but obviously invoked higher interest rates from the central bank.

- Insert Table 2 here -

Although an exact quantitative comparison with Carlino and DeFina (1998) and Arnold (2000) is not possible because of differences in model specification, our results

[12] Carlino and DeFina (2000) use an eight-quarter horizon to determine the cumulative response of output to a monetary policy shock. The choice of this window is suggested by Monte Carlo studies. These indicate that the maximum cumulative response of output arises around eight quarters after the occurrence of a monetary policy disturbance. Given the use of annual data, the eight-quarter horizon is equivalent to a two-year horizon.

[13] The cumulative impulse response estimates of the individual US states are available on request.

qualitatively confirm the earlier findings. Higher interest rates trigger a decline in real personal income, with the negative effect of monetary policy being most pronounced for the Great Lakes economy. Corroborating the sectoral findings in Arnold (2000), the magnitude of the interest rate response of real personal income is largely attributable to the negative impulse responses of earnings in (durable goods) manufacturing, finance, and construction. The mining sector mitigates the negative effects of higher interest rates in almost all US regions. The exceptions are the Great Lakes economy and the Rocky Mountains area, where earnings in the mining sector decline in response to higher interest rates. Again similar to the findings in Arnold (2000), the weakest interest rate responses are visible in government and services. Since the government and service sector are less capital-intensive than the manufacturing, construction, and mining sectors, this evidence suggests a positive relationship between the degree of capital intensity and the interest rate responsiveness of earnings.

IV. Factors behind the Industry Effects of Monetary Policy

Since industries differ in their responsiveness to monetary policy, regional differences in the effects of monetary policy can predominantly be attributed to cross-region dissimilarities in industry composition. Building on this result from our time-series analysis, this section aims to explain the variation in impulse responses across industries using two industry characteristics. Our first characteristic is business size. As discussed above, differential effects of monetary policy may arise from differences in the importance of small- and large-sized businesses. Our second characteristic is a proxy of the capital intensity of industries. By including a measure of capital intensity, we will investigate whether the interest rate response of industry earnings is indeed positively related to the degree of capital intensity.

IV.1 Cross-Section Framework

Our cross-section models are defined along two dimensions: by industry i and by geographic unit j. In order to make efficient use of all available information, cross-section estimates are derived for US states rather than for US regions. As a result, the cross-section builds on a grid that consists of 50 US states and nine industries. The upper bound on the number of industries is imposed by data constraints.[14] The appendix contains a summary of the source and the industries for which data on business size and capital intensity are collected.

The degree of capital intensity in industry i of US state j is approximated as the ratio of employment to real gross product in industry i of US state j. These ratios are averaged over the period 1977-2001. Using this definition, the degree of capital intensity is inversely related to the relative importance of employment per unit value of output. Two-dimensional business size data are available for 1992 and for the period 1997-2000.

In line with existing empirical studies, we measure business size by employment. Because of data limitations and disagreements on the definition of small business size, empirical studies make different choices on the number of employees that classifies businesses as small. We use the size definition by Loveman and Sengenberger (1991) who define a small business as a business with less than 100 employees. Henrekson and Johansson (1999) argue that the adoption of broad size categories prevents the efficient use of information since the majority of businesses employs fewer than 10 employees. Therefore, broad measures of small business size may capture effects which cannot be attributed to small firm or establishment size. To account for this criticism and to determine the robustness of the empirical results to the size definition, we divide small businesses into entities with up to 4, 9, 19, and 99 employees. Furthermore, existing studies employ measures of either firm size or establishment size. As the size distributions of firms and establishments differ markedly, this choice may also have an effect on the cross-section evidence. To determine whether the choice of the business size variable matters, we use information on both the size of firms and establishments. The cross-section analysis is carried out for two sets of model specifications; one without and one with industry effects. The analysis without industry effects determines the role of small business size as monetary transmission mechanism by estimating the model

(2) $$\Psi_{i,j} = \mu + \Theta_{i,j}\alpha + \varepsilon_{i,j}\,.$$

$\Psi_{i,j}$ depicts the value of the two-year cumulative impulse response of earnings in industry i in US state j, where i = 9 and j = 1, …, 50. $\Theta_{i,j}$ denotes the exogenous business size variable that equals the percentage share of small firms or establishments in industry i of US state j. The coefficient α measures the significance of cross-state and cross-industry size differences in explaining the interest rate response of industry earnings. $\varepsilon_{i,j}$ depicts the error term. In order to determine the relevance of capital intensity as monetary transmission channel, a univariate cross-section model is estimated that includes our proxy of capital intensity as exogenous variable. The corresponding model specification equals

[14] Descriptive statistics suggest that the District of Columbia is an outlier. We therefore omit this state.

(3) $\Psi_{i,j} = \mu + \Phi_{i,j}\beta + \varepsilon_{i,j}$,

where $\Phi_{i,j}$ represents the measure of capital intensity and □ measures the significance of cross-state and cross-industry differences in capital intensity in explaining the interest rate response of industry earnings. Finally, we also investigate the importance of capital intensity next to business size as joint determinants of the interest rate sensitivity. The corresponding model specification is

(4) $\Psi_{i,j} = \mu + \Theta_{i,j}\alpha + \Phi_{i,j}\beta + \varepsilon_{i,j}$.

The expected signs of the coefficient estimates are determined by the way in which the variables are defined. Regarding capital intensity, economic theory stipulates a positive relationship between the degree of capital intensity and the interest rate response. Since we define capital intensity on the labor side, this relationship holds when our variable displays a positive sign in estimations with the value of the cumulative impulse response estimate. Considering business size, the effectiveness of monetary policy is anticipated to be negatively related to the size of firms and establishments.

Common to model specifications (2) to (4) is the exclusion of possible interrelationships between business size and industry or between capital intensity and industry. In order to assess the robustness of the empirical results to the independence assumption, all cross-section equations are revised to also include industry dummy variables D_i . The next section illustrates the need to model interrelationships between business size and industry and capital intensity and industry.

IV.2 Independence Tests

This section reports ANOVA test statistics and the results of Chi-square independence tests to illustrate the need to account for linkages between industry and industry characteristics. Table 3 summarizes the results. The two-way analysis of variance is computed to test whether variations in the distribution of business size and in the degree of capital intensity are accounted for by industries or by regions. Panels A and B display the results for our measure of capital intensity and for the share of small businesses (defined as businesses of up to 4 employees).[15] The evidence indicates that the null hypothesis of equal average capital intensity and of equal average business size across industries and regions can be rejected at least at the one percent significance level. Furthermore, the F-statistics for the industry effect is much larger than the F-values for the regional effect, so differences in size and capital intensity are predominantly accounted for by industries rather than by regions.

- Insert Table 3 here -

[15] Since the results for businesses with 0 to 9, 0 to 19, and 0 to 99 employees do not differ from those for businesses with 0 to 4 employees, the corresponding test statistics are not reported. The results are available on request.

Additional support on the independence between industry and size is provided by Chi-square tests of independence. Panel C of Table 3 reports the results of the Chi-square test statistics for the null hypothesis of no dependence between the size distribution of businesses and industry. The entries show that the hypothesis is rejected for firms and establishments regardless of the size category, confirming the results of our ANOVA analysis.

Eichenbaum (1994) suggests that the interdependence of industry and business size is also reflected in the correlation between the cyclical sensitivity of industries and the size distribution of businesses, with small firms being particular to volatile industries. In order to assess this claim, the correlation between the cyclical sensitivity of industries and business size has been computed. Approximating cyclical sensitivity by the standard deviation of industry-specific real earnings growth, the correlation coefficient is determined for two datasets. The first dataset includes all sampled industries, while the second excludes data on the mining industry for reasons presented in section IV.3. The correlation coefficients in Table 4 typically point to a statistically significant and positive relationship between the relative share of small-sized businesses and the cyclical volatility of real earnings growth, particularly for the dataset that excludes the mining industry.

- Insert Table 4 here -

Summarizing our results thus far, business size and industry and capital intensity and industry appear to be interdependent. This finding has two interrelated implications. Firstly, conclusions as to the role of business size and capital intensity as monetary transmission mechanisms are likely to depend on the structure of the cross-section model. Specifications that disregard the relationship between industry and either business size or capital intensity are expected to yield evidence that also captures the industry effects of monetary policy. Secondly, small business size effects of monetary policy may also prevail in absence of credit market imperfections. Keeping these inferences in mind, the following sections report the evidence of our cross-section regressions.

IV.3 Cross-Section Evidence

The cross-section models are estimated by assuming cross-section heteroscedasticity and residual heteroscedasticity. In order to correct for heteroscedastic residuals, all cross-section equations are estimated by using White's (1980) heteroscedasticity consistent covariance matrix estimator. To deal with cross-section heteroscedasticity, the cross-section estimates are weighted by means of generalized least squares.

Below we report the evidence of the estimations with firm size, not establishment size.[16] This is motivated by two observations. Firstly, the cross-section estimates do not differ qualitatively across model specifications with firm and establishment size. Secondly, the coefficient estimates are very close. While the choice of the business size measure does not influence the cross-section results, the choice of the business size category matters in some instances. In view of this finding, the empirical outcomes are reported for the

[16] The empirical results of the estimations with establishment size are available on request.

four size classes. The analysis proceeds by first discussing the results of the cross-section estimations without industry dummies and next the evidence including industry dummies.

i.) Cross-Section Evidence without Industry Effects

Table 5 summarizes the results of the cross-section models that do not control for industry effects. The coefficient estimates for firm size are statistically significant and have the expected negative sign regardless of the size category. Absent industry dummy variables, the relative interest rate responsiveness of industries therefore seems to increase with the relative share of small businesses. Including capital intensity doesn't improve the results; its coefficient changes sign and is insignificant in most cases. It is significant and correctly signed only in the model that uses the firm size category of 0 to 99 employees. It is, however, insignificant or wrongly signed in the other estimates in Table 5.

- Insert Table 5 here -

The findings from the cross-section models without industry effects thus seem to support the operation of a credit channel. Since the strength of the channel is suggested to increase with the relative share of small-sized businesses in an industry, regional differences in the effectiveness of monetary policy arise from cross-region dissimilarities in the relative importance of small businesses. In contrast to business size, the degree of capital intensity has no effect on the interest rate sensitivity of industries in estimations that do not account for industry effects.

ii.) Cross-Section Models with Industry Effects

In order to determine the robustness of our evidence to the independence assumption, specifications (2) to (4) are re-estimated by including industry dummy variables. As we will see below, two conclusions arise. Firstly, inferences as to the operation and strength of the credit and interest rate channels are extremely sensitive to the incorporation of industry dummies. Secondly, the strength of the industry effect differs across sectors.

The need to control for the interdependence of industry and firm size or industry and capital intensity is most apparent for the mining sector. Motivated by the strength of the empirical evidence for the mining industry, the discussion of the interdependence effects centers on the results obtained for this sector. Table 6 reports the estimation results of the cross-section specifications (2) to (4) including the mining dummy.

- Insert Table 6 here -

For each specification of the cross-section model, the estimate of the mining dummy is statistically different from zero. The variable's positive sign indicates that the interest rate sensitivity of earnings decreases with the relative share of mining in a region. The coefficient estimates of the mining dummy are very close to each other for all cross-section models. After controlling for the mining sector, firm size becomes statistically insignificant. This finding is robust to the choice of the size category and prevails in the cross-section model with and without capital intensity. In contrast to firm size, capital intensity now helps to explain the interest rate response of industry earnings. Since its coefficient is positive in all cross-section estimations including the mining dummy, the degree of capital intensity reinforces the interest rate effects of monetary policy. This new evidence against the existence of independent business size effects in monetary transmission points to the absence of a credit channel.

Summarizing the evidence, the mining industry appears to be a strong source for business size effects in estimations that do not control for industry effects. The sensitivity of the cross-section results to the inclusion of the mining dummy is attributable to the properties of the mining sector. In comparison to the other industries, the mining sector is characterized by a high degree of capital intensity and a low share of small-sized businesses. In addition, the exceptional positive interest rate sensitivity suggests that the mining industry is supply-shock rather than demand-shock driven. Finally, the importance of industry effects is also evident in estimations that capture the effects of each industry separately.[17] The corresponding evidence typically points to a decline in the importance of small business size as monetary transmission channel.

V. Summary and Conclusion

This paper has identified and explained the industry effects of US monetary policy using industry data from US states for the sample period 1958-2000/01 and a vector autoregressive model that provides estimates of the interest rate response of industry earnings. In line with existing empirical work, the impulse response estimates point to cross-industry differences in the degree of interest rate sensitivity and, accordingly, to the operation of an interest rate channel that propagates and amplifies the effects of monetary policy changes. Regional differences in the effects of monetary policy originate from cross-region dissimilarities in the mix of industries and, consequently, from differences in regional economic structures.

In order to explain the cross-industry and cross-region heterogeneity of monetary policy effects, the analysis has introduced small business size and capital intensity as variables that may play a role in monetary transmission. We show that conclusions regarding the role of business size and capital intensity depend strongly on the assumed interdependence of these variables with industries in general and with the mining sector in particular. Empirical findings are therefore very sensitive to the incorporation of industry effects. Cross-section estimates that do not control for industry effects attribute the interest rate sensitivity of industries to the relative share of small firms in an industry and, hence, to the operation of a credit channel. In these models, capital intensity does not add anything. However, opposite conclusions can be drawn from cross-section specifications that account for the interrelationship between industry and either business size or capital intensity using industry dummies. The corresponding empirical results indicate that industry effects dwarf the effects of business size, but not those associated with capital intensity. Particularly strong industry effects are found for the mining sector. The evidence, hence, supports Eichenbaum’s (1994) view and we conclude that any test

[17] To conserve on space, the results are not reported. They are available on request.

for the existence of a credit or interest rate channel of monetary transmission should control for industry effects.

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Table 1 Two-Way Analysis of Variance

	ANOVA I					ANOVA II				
Source of Variation	**SS**	**DF**	**MS**	**F-Value**	**p-Value**	**SS**	**DF**	**MS**	**F-Value**	**p-Value**
Industries	0.315	10	0.0315	71.489	0.000	0.0437	10	0.0044	46.222	0.000
Regions	0.105	50	0.0021	4.785	0.000	0.0037	7	0.0005	5.665	0.000
Error	0.220	500	0.0004			0.0066	70	0.0001		
Total	0.641	560				0.0540	87			

Note: ANOVA I depicts the results of the two-way analysis of variance for 51 US States and 11 industries. ANOVA II presents the results of the corresponding analysis with the 8 BEA regions.

Table 2 Cumulative Impulse Responses, US Regions, 1958-2001[18]

	US	NENG	MEST	GLAK	PLNS	SEST	SWST	RKMT	FWST
Real Personal Income	-0.0165	-0.0194	-0.0104	-0.0301	-0.0180	-0.0177	-0.0162	-0.0218	-0.0184
Earnings in:									
Total Goods Manufacturing	-0.0492	-0.0278	-0.0340	-0.0710	-0.0532	-0.0508	-0.0432	-0.0415	-0.0299
Durable Goods Manufacturing	-0.0586	-0.0292	-0.0409	-0.0845	-0.0697	-0.0657	-0.0563	-0.0492	-0.0290
Nondurable Goods Manufacturing	-0.0332	-0.0336	-0.0255	-0.0361	-0.0288	-0.0403	-0.0220	-0.0237	-0.0265
Services	-0.0150	-0.0169	-0.0058	-0.0206	-0.0200	-0.0181	-0.0109	-0.0232	-0.0177
Government	0.0017	-0.0083	0.0025	-0.0012	0.0038	-0.0006	0.0024	0.0014	0.0048
Agriculture	-0.0223	-0.0154	-0.0166	-0.0185	-0.0066	-0.0308	-0.0220	-0.0172	-0.0273
Mining	0.0132	0.0321	0.0186	-0.0077	0.0181	0.0121	0.0431	-0.0138	0.0502
Construction	-0.0696	-0.0583	-0.0445	-0.0815	-0.0659	-0.0818	-0.0528	-0.0619	-0.0557
Wholesale Trade	-0.0186	-0.0233	-0.0113	-0.0237	-0.0116	-0.0250	-0.0103	-0.0130	-0.0198
Retail Trade	-0.0303	-0.0242	-0.0179	-0.0374	-0.0324	-0.0357	-0.0252	-0.0350	-0.0279
Transportation	-0.0293	-0.0237	-0.0227	-0.0410	-0.0322	-0.0326	-0.0217	-0.0303	-0.0239
Finance	-0.0467	-0.0349	-0.0319	-0.0438	-0.0489	-0.0519	-0.0375	-0.0664	-0.0506

Note: US = US aggregate, NENG = New England, MEST = Mideast, GLAK = Great Lakes, PLNS = Plains, SEST = Southeast, SWST = Southwest, RKMT = Rocky Mountains, FWST = Far West.

[18] See the notes on end-of-sample missing values in the appendix .

Table 3 Independence Tests

Panel A Two-Way Analysis of Variance of Business Size

	Firms with 0 to 4 Employees					Establishments with 0 to 4 Employees				
Source of Variation	**SS**	**DF**	**MS**	**F-Value**	**p-Value**	**SS**	**DF**	**MS**	**F-Value**	**p-Value**
US States	0.365	49	0.007	2.772	0.000	0.578	49	0.012	3.850	0.000
Industries	4.932	8	0.616	229.446	0.000	5.699	8	0.712	232.640	0.000
Error	1.053	392	0.003			1.200	392	0.003		
Total	6.350	449				7.477	449			

Panel B Two-Way Analysis of Variance of Capital Intensity

	Degree of Capital Intensity				
Source of Variation	**SS**	**DF**	**MS**	**F-Value**	**p-Value**
US States	0.0000000020	49	0.000	1.689	0.004
Industries	0.0000000483	8	0.000	255.166	0.000
Error	0.0000000093	392	0.000		
Total	0.0000000595	449			

Panel C Chi-Square Independence Tests of Business Size and Industry

	Test 1		Test 2		Test 3		Test 4	
	FS	**ES**	**FS**	**ES**	**FS**	**ES**	**FS**	**ES**
Estimated Chi-Square Value	5333.89	8936.11	4610.05	8252.13	3629.59	7328.74	2026.91	5807.88
Critical Chi-Square Value (α = 0.01)	63.7	63.7	50.9	50.9	42.98	42.98	32.0	32.0
Degrees of Freedom	40	40	32	32	24	24	16	16
p-Value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: The tests statistics are computed for the 1992-2000 unweighted US average by taking into account the size distribution of firms (FS) and establishments (ES) in agriculture, mining, construction, manufacturing, wholesale trade, retail trade, transportation, and insurance. The computations are carried out by excluding the District of Columbia.
Test 1 includes businesses with 0 to 4, 5 to 9, 10 to 19, 20 to 99, 100 to 499, and more than 500 employees. Test 2 includes businesses with 0 to 9, 10 to 19, 20 to 99, 100 to 499, and more than 500 employees. Test 3 includes businesses with 0 to 19, 20 to 99, 100 to 499, and more than 500 employees. Test 4 includes businesses with 0 to 99, 100 to 499, and more than 500 employees.

Table 4 **Correlation between Business Size and the Volatility of Industry Earnings**

	SC 0-4	SC 0-9	SC 0-19	SC 0-99
Firm Size a)	0.08***	0.01	-0.03	-0.15*
Establishment a)	0.16*	0.13*	0.17*	0.21*
Firm Size b)	0.44*	0.42*	0.40*	0.32*
Establishment b)	0.59*	0.54*	0.60*	0.61*

Note: SC depicts the size category for which estimates are derived.
a) indicates that the correlation coefficient is computed across all US states (except the District of Columbia) and across all sampled industries including the mining sector. The number of observations T is 450.
b) indicates that the correlation coefficient is computed across all US states (except the District of Columbia) and across all sampled industries excluding the mining industry. The number of observations T is 400.
*, **, *** depict the statistical significance at the one, five, and ten percent level, respectively, for critical values from the two-tailed student t-distribution.

Table 5 Cross-Section Estimations without Industry Dummy

	Size Category 0 to 4		Size Category 0 to 9		Size Category 0 to 19		Size Category 0 to 99		Size Independent
Constant	0.004* (0.005)	0.010*** (0.006)	0.021* (0.007)	0.023* (0.008)	0.042* (0.011)	0.042* (0.011)	0.123* (0.020)	0.133* (0.021)	-0.026* (0.002)
Firm Size	-0.060* (0.009)	-0.063* (0.009)	-0.070* (0.010)	-0.070* (0.010)	-0.086* (0.013)	-0.086* (0.013)	-0.164* (0.022)	-0.179* (0.024)	
Capital Intensity		-207.21* (74.754)		-101.33 (71.330)		-3.55 (73.163)		192.31** (82.511)	-119.86 (76.488)
N	450	450	450	450	450	450	450	450	450
Adj. R^2	0.21	0.22	0.22	0.22	0.22	0.21	0.23	0.24	0.13
F-Statistic	122.65*	63.24*	128.29*	63.99*	124.31*	62.02*	132.72*	71.26*	70.88*

Note: The dependent variable is the non-absolute cumulative impulse response estimate of the four-variable VAR model. The variables in the first column are the independent variables. Rows labeled 'Firm Size' contain the estimates for the percentage share of businesses that belong to one of the four employment size categories given in the header of the table. N depicts the number of cross-sections used. The estimates are derived for cross-section weights, iterated to convergence. Being reported in parentheses, the standard errors are adjusted for heteroscedasticity. *, **, *** depict the statistical significance at the one, five, and ten percent level, respectively, for critical values from the two-tailed student t-distribution.

Table 6 Cross-Section Estimations with Dummy for the Mining Industry

	Size Category 0 to 4		Size Category 0 to 9		Size Category 0 to 19		Size Category 0 to 99		Size Independent
	-0.028* (0.004)	-0.033* (0.004)	-0.030* (0.005)	-0.034* (0.005)	-0.034* (0.007)	-0.036* (0.007)	-0.042* (0.015)	-0.035** (0.015)	-0.036* (0.001)
	-0.009 (0.006)	-0.006 (0.006)	-0.005 (0.007)	-0.003 (0.007)	0.001 (0.009)	-0.0003 (0.009)	0.009 (0.016)	-0.002 (0.016)	
		141.97* (54.365)		152.57* (52.205)		154.71* (52.015)		156.72* (55.537)	154.47* (51.759)
	0.063* (0.003)	0.064* (0.003)	0.064* (0.003)	0.065* (0.003)	0.064* (0.003)	0.065* (0.003)	0.065* (0.003)	0.065* (0.003)	0.065* (0.003)
	450 0.51 239.34*	450 0.52 165.04*	450 0.52 240.11*	450 0.52 165.96*	450 0.52 242.05*	450 0.53 166.95*	450 0.52 243.18*	450 0.53 166.87*	450 0.53 251.04*

Note: See the notes to Table 5.

Appendix

Data Sources and Descriptions

Table 1 Description of Industry Earnings Data

- Table A.1 summarizes the data availability of industry earnings for US states, US regions, and the US aggregate.

Panel A General Description

Industries	Source	Sample Period
Total (Personal Income); Agriculture, Forestry, Fishing, & Other; Mining; Construction; Manufacturing; Durable Goods Manufacturing; Nondurable Goods Manufacturing; Wholesale trade; Retail Trade; Transportation & Warehousing; Transportation & Public Utilities; Finance & Insurance; Real estate & Rental, & Leasing; Services (total); Government	US Bureau of Economic Analysis - Regional Economic Information System (2002)	1958-2001

Note: For some industries, the sample period is shorter. See the Table below.
The variables transportation and finance also contain information on other industry sectors. In the subsequent tables, transportation and finance are used as synonym for the wider classification.

Panel B Missing Values

	End-of-Sample Missing Values		In-Sample Missing Values	
Industries	**US State/ Region**	**Sample Period**	**US State/ Region**	**Sample Period**
Agriculture, Forestry, Fishing, & Other	Idaho, Minnesota, District of Columbia, Mideast, Plains, Rocky Mountains, Delaware	1958-1998		1958-1997
Mining	Idaho, Minnesota, Mideast, Plains, Rocky Mountains,	1958-1998	Delaware, District of Columbia, Hawaii	1958-1997
Retail Trade	Florida	1958-2000		
Transportation & Warehousing	US Aggregate	1958-2000		
Real estate & Rental, & Leasing	US Aggregate	1958-2000	Connecticut, Delaware, Iowa, Maine, Michigan, Montana, Ohio, Pennsylvania, Rhode Island, South Dakota, Vermont, West Virginia, Wisconsin, Wyoming	1958-1997

Table 2 Description of Firm Size and Establishment Size Data

- The data are available along two dimensions, i.e., by industry and by US state.
- In contrast to the data on industry earnings, the classification of industries is not invariant to the choice of year. Differences in the definition of industry sectors are particularly pronounced for agriculture and transportation.
- The data are compiled from the US Bureau of Economic Analysis (2003), respectively.

Industries	Sample Period	Industries	Sample Period
Total	1992, 1997	**Total**	1998-2000
Agriculture, Forestry, Fishing	1992, 1997	**Agriculture, Forestry, Fishing, & Hunting**	1998-2000
Mining	1992, 1997	**Mining**	1998-2000
Construction	1992, 1997	**Construction**	1998-2000
Manufacturing	1992, 1997	**Manufacturing**	1998-2000
Wholesale trade	1992, 1997	**Wholesale trade**	1998-2000
Retail Trade	1992, 1997	**Retail Trade**	1998-2000
Transportation & Communication, & Utilities	1992, 1997	**Transportation & Warehousing**	1998-2000
Finance & Insurance, & Real Estate	1992, 1997	**Finance & Insurance**	1998-2000
Services (total)	1992, 1997	**Services (total)**	1998-2000
		Real Estate & Rental, & Leasing	1998-2000
		Utilities	1998-2000
		Sub-Categories of Services [A]	1998-2000

Note[A]: The subcategories of services are professional, scientific, and technical services; management of companies and enterprises; auxiliaries, executive corporations, subsidiary, and regional managing offices; administrative, support, waste management, and remediation services; educational services; health care and social assistance; arts, entertainment, and recreation; accommodation and foodservices; other services (except public administration); information. The level of aggregate services is computed as the sum of the subcategories.