The Effects of Unions on Research and Development:

An Empirical Analysis Using Multi-Year Data

JULIAN R. BETTS*, CAMERON W. ODGERS and MICHAEL K. WILSON

*Department of Economics,

University of California, San Diego,

jbetts@ucsd.edu

(858) 534-3369

This paper is forthcoming in the *Canadian Journal of Economics*. The Data Appendices in this discussion paper will not appear in the published version.

Julian Betts is an Associate Professor, Cameron Odgers is a Ph.D. graduate, and Michael Wilson is a graduate student, all from the Department of Economics, University of California, San Diego. We would like to thank Peter Dungan for providing input-output data, Stephen Jones and two anonymous referees for very helpful suggestions, and the Social Sciences and Humanities Research Council of Canada and UCSD for research support.

ABSTRACT

The paper tests for a link between unionization and research and development rates (research and development expenditures divided by output) in thirteen aggregate Canadian industries. A balanced panel of thirteen industries covering 1968 to 1986 reveals a negative relationship between industry unionization rates and research and development. The results hold when using a number of techniques to control for unobserved industry heterogeneity and non-linear responses to unionization. In an industry that moves from the 25th to the 75th percentile of unionization, research and development is predicted to fall by about 40%.

JEL Classification: J51

1. INTRODUCTION

Research and development (R&D) is a major contributor to future economic growth. It is therefore important to understand how the economic milieu in which firms operate influences their investment in research. If the presence of unions affects firms' incentive to invest, the decision by a group of workers to unionize could have long-lasting effects on the economy. This paper examines the relationship between the level of industry unionization and industry research and development (R&D) investment in Canada for the period 1968-1986. This is an interesting empirical issue because the theoretical impact of unions on investment is uncertain.

There are two competing models for union effects on investment. The traditional on-the-demand-curve model treats the union wage increase as a tax on labor. Due to opposing scale and substitution effects, the net effect of the union tax on investment is uncertain. In contrast, the union rent-seeking model (e.g., Hirsch 1991) suggests that labor unions will reduce investment below that of a similar firm with a nonunion labor force. In this model, unions capture some of the firm's quasi-rents from capital (tangible or intangible).[1] This behavior reduces firms' incentive to invest.

This paper is the first of which we are aware on the link between R&D investment and unionization in Canadian industry. Most of the evidence to date has examined American data. It is of interest to study this question in a Canadian context for a number of reasons. First, as Riddell (1993) shows, the levels of private sector unionization in Canada and the United States have diverged considerably. Private sector union density has declined in both countries, but the decline in the United States has been much larger. A second advantage of studying this question in a Canadian context is that the data on unionization are unusually good. Under the requirements of the Corporations and Labour Unions Returns Act, unions file detailed reports of membership to the government on an annual basis. In contrast, most American research to date has used detailed firm data matched to a single observation of unionization at a point in time. By using Canadian data, errors resulting from measurement error on the union variable or inappropriate specification resulting from panel estimation on a single union observation are reduced.

2. THEORETICAL MODEL AND LITERATURE REVIEW

Baldwin (1983), Crawford (1988), Grout (1984) and Van der Ploeg (1987) show that under short-term contracting a firm's quasi-rents are vulnerable to capture by unions through the threat of strike. Because part of the competitive return is captured by unions, firms will reduce investment in both physical and R&D capital.[2]

Unions are able to capture quasi-rents accruing to physical capital because these assets are difficult to move. Once physical capital is in place, the firm cannot costlessly resell or move such capital. If local labor market conditions do not permit the substitution of non-union labor during a strike, then the inability to sell or move installed physical capital provides an incentive for the firm to share some of the quasi-rents that comprise part of the normal competitive return to capital investment. The result is a lower level of investment than would be undertaken by a similar non-union firm.

R&D investment might be immune to such union rent seeking. Production processes or new products can be licensed to other firms, eliminating the union's ability, through the threat of strike, to appropriate quasi-rents accruing from R&D investment. However, there are several factors which reduce the ability of firms to avoid rent-sharing with unions through licensing. New production processes may only be of value to the discovering firm. If the production techniques of two firms are substantially different, an improvement in one sub-process may have no value outside a firm. New product development may not be transferable either. In the automobile industry the "Big Three" automobile manufacturers do not generally license new car designs from competitors. This may be the result of difficulties in coordinating plant tooling with new car design across firms. This effect would be exacerbated by short product life-cycles. Additionally, licensing agreements may be costly to monitor, thereby reducing the return to R&D investment. A final factor mitigating a firm's ability to license proprietary technology is current patent law. When a firm patents an invention, a substantial amount of proprietary information becomes public. Other firms may be able to use such information to develop similar products or processes which vary sufficiently so that they do not violate the patent but provide substantially the same economic benefits.[3] All of the above factors may decrease a firm's ability to use licensing to protect R&D revenues from unions, and so these factors may increase a firm's willingness to share quasi-rents from R&D investment with its unions. The result would be the same as for physical capital. Firms would eliminate R&D expenditures that a similar nonunion firm would be willing to undertake.

There are several empirical studies of the union impact on R&D investment in the United States. Connolly, Hirsch and Hirschey (1986) use a cross-section of 367 Fortune 500 firms for the year 1977 which matches three digit industry union data to firm level investment data. An increase in unionization from 0 to their sample average of 39.1% is predicted to reduce research and development (R&D) divided by sales by about 32%.[4] In firm-level analysis of 315 firms, Hirsch (1990) matches firm investment and other firm and industry data including industry dummies covering the period 1970 to 1980 to union data for 1972. He finds an 11 percent reduction in R&D investment for the typical unionized manufacturing firm. Hirsch (1992) uses a larger sample and an updated unionization measure based on a survey he conducted and finds the total union effect on R&D spending to be -27.1%.[5] In an interesting paper which examines the effects of measurement error in the union coverage variable, Bronars, Deere, and Tracy (1994) find that a 10% increase in the unionization rate reduces R&D investment in manufacturing by about 3.5-5%, so that at a level of overall unionization of 33.3%, as reported in Hirsch (1992), overall R&D would be reduced by 12-17%; however, the coefficient on the union variable becomes insignificant and changes sign when a firm-level first-difference model is estimated. The authors find weaker evidence of a significant negative impact of unions on R&D outside of manufacturing.

Addison and Wagner (1994) find a positive cross-sectional correlation between unionization and R&D in the United Kingdom, but the correlation disappears after controlling for German R&D, leading them to conclude that the effect is not causal. Similarly, Menezes-Filho, Ulph and Van Reenen (1998) find little correlation between R&D and unionization in the U.K., either in a cross section or in a panel of firms, after controlling for the age of the firm and traits of the industry. They find that Hirsch's American data-set is robust to their change in specification, leading them to conclude that British unions may differ in their objectives from their American counterparts, perhaps by stressing job security over wage hikes, thereby obviating the implicit union tax on R&D.

The largest limitation of most of these papers is the mainly cross-sectional nature of their identification strategies. Hirsch (1990,1992) estimate panels with a single observation on unionization, whereas, Bronars, Deere, and Tracy (1994) have multi-year union data, but most of their regression analysis is done on sample averages for each variable. The change in results when using a firm-level first difference between means in 1975-78 and 1979-82 raises questions about the robustness of the overall relationship between unionization and R&D. This issue might be resolved by using a panel with multi-year data on unionization.

3. DATA AND EMPIRICAL SPECIFICATION

The data set contains observations for 13 Canadian manufacturing and natural resource industries on profits, taxation, R&D expenditures, employment, industry concentration, union membership, imports, and exports. The final data set is a balanced panel containing 247 industry/year observations for the period 1968 through 1986. Table 1 lists the industries used. [6]

Union data were provided by Statistics Canada (various years) based on information submitted annually under the Corporations and Labour Unions Returns Act. Data on industry imports, exports, final sales, and employment were computed from the University of Toronto input-output matrix. R&D expenditure data were provided by the Services, Science and Technology Division of Statistics Canada. Detailed data descriptions appear in the two appendices.

This longitudinal industry-level data-set confers both advantages and disadvantages relative to earlier work with U.S. data. The obvious disadvantage is that it cannot control for changes in the composition of each industry. In particular, a pattern of falling unionization and rising R&D investment in an industry may reflect the entry of new non-unionized firms into highly unionized industries. But if such a process occurs, then industry level data might be the more appropriate data for estimating the *overall* impact of unionization on an industry (and hence on the economy): whereas a firm-level study might indicate that unionization dramatically reduces investment, if entry barriers into the industry are low, then this estimate would overstate the impact of unionization on investment in the industry as a whole.

A second advantage of using industry-level data is that a firm-level analysis may *understate* the overall impact of unionization on investment. If non-unionized firms observe certification of a union at another firm in the industry, they may feel compelled to increase wages in order to prevent their own workers from unionizing (Rosen, 1969). Consequently, investment may fall even at non-union firms. Indeed, a recent paper by Bronars and Deere (1994) finds that petitions to certify a union at a given firm have a significantly negative impact on the stock market value of both that firm *and of other firms* in the industry. If such union threat effects exist, the use of industry-level data will capture the overall true impact of unionization on an industry, while firm-level data will understate the impact. These two sources of bias, from firm entry and exit and from spillovers caused by the union threat effect, work in opposite directions in firm-level studies, so the direction of any net bias remains uncertain.

A third advantage of the present data-set is that it contains highly accurate measures of unionization, which must be reported to the Canadian government by law.

A fourth advantage of the data-set is that it contains annual observations on the level of unionization in each industry. In the United States, one could construct a time series on unionization by industry using Current Population Survey data, but unlike the data in the present paper such data are based on a sample rather than a census. To the best of our knowledge, only one American study uses a long time series on unionization. As discussed above, Bronars, Deere and Tracy (1994) obtain somewhat imprecise results when they fully utilize the time-series aspects of their unionization data. [7]

3.1 Empirical Specification

A baseline specification uses ordinary least squares (OLS) regression of real R&D expenditures normalized by real Gross Domestic Product (GDP) on various control variables including industry union density:

$$I_{it} = \Sigma\beta_j X_{jit} + \psi \cdot UN_{it} + e_{it}$$

(1)

where I_{it} is real R&D expenditures for industry i in time t divided by real industry GDP.[8] In the specifications examined in this paper, the vector $\mathbf{X}_{it}$ contains observations of industry characteristics thought to affect R&D expenditures including measures for import share of domestic market, industry concentration (Herfindahl index), industry growth rates in real GDP over 4 years, expressed as a proportion, and profit rates.[9] The union variable UN_{it} is the union participation rate obtained by dividing industry union membership by industry employment. The coefficients to be estimated are β_j and ψ. Note that R&D investment is reported as a rate (i.e., it is obtained by dividing industry R&D expenditures by industry GDP) since many of the regressors such as import shares and unionization are themselves proportional variables.

Most of the studies cited above, as well as others, find that in many cases unions have larger marginal effects on profits and investment at low levels of unionization. If these nonlinear effects are not modeled, the coefficient on the union participation rate variable will be biased. For this reason, in addition to estimating a model where union rates enter linearly, we also estimate a union rate spline specification.

There are two possible explanations for these nonlinear effects. First, if a firm in an industry becomes unionized, other firms in an industry may increase wages to prevent their workers from unionizing (Rosen, 1969). This would tend to amplify the impact of union organizing at low rates of industry unionization. Once an industry becomes significantly unionized, many of the non-union firms behave as if they were unionized. Hence union organizing of the last non-union firms should have small marginal effects. Another factor affecting the marginal impact of unionization is the potential for imperfect substitutability between different types of labor in the production process. Suppose there are two types of labor (such as administrative and production workers). If administrative employees cannot be easily substituted for production workers, then production workers can shut down production. This implies that organizing administrative workers does not increase union bargaining power once production workers are organized. The result of further union organizing is competition by the two types of labor over the distribution of quasi-rents. Again it should be expected that unions would have smaller marginal effects at high rates of industry unionization.

We choose to estimate two basic models. One may be considered a reduced form investment equation, meaning profits were not added as an explanatory variable. Liquidity constraint models indicate that profits, or cash flows in general, may affect investment. But profits likely depend on the rate of unionization. If unionization affects profits, then by including profits as a regressor, the resulting coefficient on the union rate variable will under-estimate the true impact of unionization on R&D expenditure rates. In particular, as found in most of the references cited in the literature review, unions appear to have a negative effect on profits. This would imply that the coefficient on the union variable is biased up (down in absolute value). Since our goal is to analyze the overall effect of unions on investment, our primary model does not include profits as a regressor. However, we also estimate a specification which models R&D as a function of the previous year's profit rate.

4. RESULTS

A preliminary analysis is conducted in Table 1 with individual industry regressions. We regress R&D expenditure rates on a constant and the unionization variable. It can be seen that ten of the estimated coefficients on the unionization rate are negative. The negative effect of unionization appears to be particularly strong and significant in three industries while a large positive and significant effect can only be found in one industry (chemicals).

INSERT TABLE 1 ABOUT HERE

Five figures provide insights into the data. Figure 1 provides plots of all observations in the sample for the unionization rate and R&D expenditure rate. The figure suggests a negative relationship between expenditure rates and unionization rates. The points with the highest R&D expenditure rates are from the electrical products and petroleum and coal products industries.[10] Figure 2 shows 13 observations that correspond to the within-industry changes in the unionization rate and R&D expenditure rates over the span of the sample. The vertical axis indicates the change in R&D expenditure rates from 1968 to 1986, and the horizontal axis shows the corresponding change in the unionization rate. Again the electrical products industry is prominent as the point in the north-west corner. The effects of the electrical products industry on the ensuing econometric analysis will be analyzed more extensively later in this section.

INSERT FIGURES 1&2 ABOUT HERE

In order to probe the time-series aspects of the data, Figure 3 shows the mean R&D and union rates by year, with the former multiplied by 20 to enable both trends to appear clearly on the graph. It appears that on average unionization rates began to decline in 1973. R&D rates have been much more volatile. They began to increase fairly steadily beginning in 1976. The correlation between the two variables, averaged by industry, is –0.68. Re-analysis using means by year that were weighted by industry GDP, in Figure 4, shows a slightly stronger negative relation between R&D and unionization. With weighted data, the correlation between the two series becomes more negative, falling to –0.73. While these figures suggests a negative relation between R&D and unionization, especially after the mid-1970's, it is important to bear in mind that these averages hide a tremendous amount of inter-industry variation in trends, as implied by Figure 2.

INSERT FIGURES 3&4 ABOUT HERE

Finally, Figure 5 plots trends in the numerator and denominator of the R&D and union rates. (R&D spending is normalized by GDP and union membership is normalized by employment.) It is useful to examine trends in the four underlying variables to ensure that most of the variation in the R&D rate and union rate comes from the respective numerators – real R&D spending and union membership. Figure 5 makes clear that this is the case. R&D has risen steadily since the mid 1970's, while average GDP in these industries has grown far more slowly. However, it is worth noting that some of the decline in the R&D rate before that time, as shown in Figure 3, derives from quite steady R&D spending combined with rising GDP. As for the union rate, Figure 5 suggests that union membership has been considerably more volatile than overall employment in the industries under study. For instance, most of the decline in the union rate between the late 1970's and 1986 comes from an absolute decline in union membership, given that overall employment in these industries stagnated during the same period. [11] We conclude that changes in R&D and unionization have trended in the opposite direction over time, that the strongest correlation appears after 1975, and that variations in R&D spending and union membership have been the driving forces behind trends in the respective rates. However, Figure 1 makes clear that trends in R&D and unionization have varied substantially across industries, thus meriting a formal analysis by industry over time.

INSERT FIGURE 5 ABOUT HERE

The main regression results are presented in Table 2. In order to control for unobserved industry effects, the OLS regression uses fixed effects for each industry. Fixed effects results are presented because a test of the joint significance of the industry intercepts (P-Val Pool vs FE) implies pooled OLS is rejected in favor of fixed effects at a significance level of 0.000 (that is, < 0.0005). The constant is equivalent to the industry intercept for the industry without a dummy variable. The inclusion of these fixed effects is useful given the aforementioned British evidence that some of the link between unionization and R&D in Britain appears to be caused by industry-specific unobserved effects.

Furthermore, the estimates are robust to heteroskedasticity as White standard errors are employed. The values in parentheses are the t-statistics corresponding to the estimated coefficients. In all of the following tables except for Tables 3 and 4, White standard errors will be reported. In practice, the t-statistic on the unionization variable is only little changed when calculated without the heteroskedasticity correction.

Regression (1) regresses R&D expenditure rates on variables thought to affect R&D expenditures. Import Share and Herfindahl were included to control for differences in R&D expenditure rates resulting from different levels of industry competition. Because Canada is a small open economy, Import Share may be the superior measure of competition within an industry. The four year industry growth rate (Growth4) is included to control for the effects of long-term industry growth on R&D expenditure rates. The results show that Import Share and the Union Rate are the two most important predictors of R&D investment rates, which have highly positive and negative coefficients respectively.

In the remaining columns of Table 2, alternative specifications are estimated that include profits and/or a time trend. Inclusion of a time trend does not appear to materially affect the estimates of the other coefficients, and because its coefficient has only marginal significance, most of the later regressions do not include a time trend. Removing the profit variable increases the magnitude of the estimated union coefficient and the corresponding t-statistic. The larger magnitude of the union effect on R&D rates when profits are removed may be due to a negative union effect on profits and a positive effect of profits on R&D expenditures.[12] If unions discourage spending on R&D in part by reducing firms' profits then the equations which condition on profits pick up only one part of the effect of unions on R&D. For these reasons we think that the ‘reduced form’ estimates in the first two columns are the more reliable estimates of the overall impact of unions on R&D.

INSERT TABLE 2 ABOUT HERE

The estimated coefficients on the other regressors in Table 2 warrant some analysis. Surprisingly, the coefficient on the four year growth rate is insignificant and negative, suggesting that growth in output is not a major determinant of R&D spending rates. However, Connolly, Hirsch, and Hirschey (1986) obtained similar results. The coefficient on the Herfindahl index is insignificant which should be expected in a relatively small open economy regardless of the expected sign. In such an economy the import share of the domestic market would be a better measure of competitive pressures in manufacturing industries than measures of industry concentration. This view is supported by the results. The positive and significant coefficient on the import share variable indicates that increased competition results in higher R&D expenditure rates.

Some caution is merited by the value of the Durbin-Watson statistic near the bottom of Table 2. This value indicates the possibility of serial correlation of the disturbance term. Although the Durbin-Watson statistic is strictly valid only under homoskedasticity, we re-estimate the t-statistics for models (1) and (3) based on a consistent covariance matrix using the Newey and West (1987) procedure. This procedure simultaneously controls for both heteroskedasticity and autocorrelated errors. We set the number of lags equal to two.[13] By using this method the values of the t-statistics on the union variable are reduced slightly, but unionization remains highly significant (for (1) and (3) the values are (-2.81) and (-2.72) respectively).

Although pooled OLS was strongly rejected against fixed effects, it is useful to know what the regressions yield without the industry fixed effects. After all, part of the union impact may work through these industry fixed effects. For specification (1), (2), (3), and (4), the coefficient estimates on the unionization rate for pooled OLS (without industry dummies) are -0.07,-0.07,-0.04,-0.04 respectively. The corresponding t-statistics are -5.98, -6.07, -4.01, and -4.13. Thus both the level of significance and the estimated effect of unionization are generally higher in the OLS specifications than in the fixed effect models in Table 2. Given that the null of OLS was strongly rejected against fixed effects, we focus on the more conservative fixed effect specifications in the remainder of the paper.

An additional problem with the OLS model is that it ignores the possibility of correlated errors across years within each industry, which can lead to inflation of the t-statistics if not corrected. To handle this issue, Table 3 presents the results from a random effects specification. Random effects estimates can yield more efficient estimates than fixed effects; however, if there is correlation between the random effect and the regressors, the estimated coefficients will be neither unbiased nor consistent. The results of a Hausman test for such correlation are shown near the bottom of Table 3 (P-Val REvsFE). The test indicates that the random effects specification is retained with a p-value of 0.22 or higher. The random effects t-statistics on the union rate are similar to those obtained by fixed effects estimation, but, as expected, smaller than in the OLS estimates. Notably, the coefficients on unionization are uniformly larger in the random effects models than in the fixed effect models. [14]

INSERT TABLE 3 ABOUT HERE

While the fixed effect estimates will control fully for unobserved traits of industries that did not change over time, they also remove any impact of unionization that is fixed within each industry over time. The random effect and OLS models do the opposite – they do not control for unobserved traits of industries that are fixed over time, but do allow for inter-industry variations in the mean level of unionization to influence the results. One compromise involves estimating random effect models that control for R&D spending rates in one or more nearby countries. [15]

Freeman (1992) was the first to suggest this method of controlling for cross-industry determinants of R&D. Addison and Wagner (1994) implement the idea in their model of R&D rates in the United Kingdom by adding German R&D as a control. We adopt a similar approach, repeating the random effect models in Table 3 with American R&D rates as an additional regressor. Because of some inconsistencies between the industry aggregations in the Canadian and American R&D data, we had to drop two industries, "Mining, Quarries, and Oil Wells", and "Nonmetallic Minerals". (Estimation of the earlier models on this restricted sample produced similar results to those in Table 3. For instance, model (1) from Table 3 produced a coefficient and t-statistic on the union rate variable of –0.061 and –3.53 respectively.)

Overall, the correlation between the Canadian and American R&D rates was 0.46. Table 4 presents random effect models identical to those in Table 3 except that the American R&D rate is added as a regressor. The results are surprisingly close to those in Table 3, with slightly higher coefficients on the unionization variable than in Table 3. Even though Canadian and American R&D rates are quite highly positively correlated, other regressors in the models, such as the unionization variable, industry growth, and import share, appear to capture most of the variation in the U.S. R&D measure, which never comes even close to being significant. This finding contrasts with the results of Addison and Wagner, who found that in the U.K. unionization and R&D were *positively* correlated, but after controlling for German R&D intensity, no relation was found. In contrast, we find a consistently negative relation. The robustness of our finding to the addition of controls for American trends in R&D spending increases our confidence that we have found a causal negative relation between unionization rates and R&D spending.

INSERT TABLE 4 ABOUT HERE

In the original specification found in Table 2, each industry is given equal weight. We would like to know whether the estimated link changes appreciably if in the fixed effect models we use industry weights. It is important to use weights because it is undesirable to have small industries contributing the same as large industries in the regression results. Table 5 repeats the models of Table 2 using real GDP in each industry for the given year as a regression weight. The table shows quite similar results, with nearly identical levels of significance and coefficients that are lower by about 10-15%. Although the results from the Weighted Least Squares are similar, we prefer not to use industry weights for two reasons. First, the random effect models themselves are weighted regressions because they are estimated using Generalized Least Squares, which precludes weighting for industry size. Comparable estimates between the fixed effect and random effect models are possible only if we do not weight by industry size. Second, because much of the identification of the union effect appears to be coming from *within-industry* variation, we want to give each industry an equal weighting.

INSERT TABLE 5 ABOUT HERE

We undertook two further robustness checks. The magnitude of the union effect on R&D expenditures in conjunction with Figure 2 causes concern regarding the presence of outliers or nonlinear effects. Tables 6 and 7 therefore focus on potential outlier effects and nonlinear union rate effects respectively. Table 6 repeats estimates of model (1) from Table 2 on subsamples. Model (1A) deletes four observations with high leverage, and which were potentially influential.[16] The simple industry-by-industry regressions in Table 1 together with the graphical analysis suggests that "Chemicals" and "Electrical Products" were outlier industries at the two ends of the distribution. As previously discussed Electrical Products has the highest R&D expenditure rates as well as the largest 19 year increase in R&D expenditure rate and among the largest decreases in unionization rate. The Chemicals industry is unique in that both unionization and R&D fell between 1968 and 1986. (It is the only industry in the third quadrant in Figure 2.) Accordingly, models (1B), (1C) and (1D) repeat model (1) from Table 2 after deleting first

Chemicals, then Electrical Products, then both. It should be noted that in (1A) only one of the observations found to have high leverage was from the electrical products industry.

INSERT TABLE 6 ABOUT HERE

In each case, we find that union rates continue to bear a significant relation with R&D rates. However, when we exclude Electrical Products the magnitude of the estimated coefficient is substantially smaller than in other models. But the impact on investment is still large. We also re-estimated model (3) from Table 2 in the same ways. We found that union rate remained highly significant.

Table 7 examines nonlinear union effects. A union spline specification is estimated, which assumes a continuous and piecewise linear relationship between R&D and the unionization rate, but which allows a kink. Models (1) and (3) were re-estimated in this way, with every possible location for the kink being estimated on a grid search over the Union Rate, with increments of 0.01. The criteria for placement of the single knot was the value which yielded the highest adjusted R-squared. (When the loglikelihood was instead used as the criterion, the same model was chosen in each case.) For model (1), the knot (or kink) was placed at Union Rate = 0.48. The variable that is labeled "Union Spline Term" is set to 0 for values of Union Rate ≤ 0.48 and to (Union Rate - 0.48) for cases in which Union Rate > 0.48, thus allowing for a change in the slope of the relation between R&D investment and unionization at this point. Similarly, the model selection criterion suggested a knot at 0.48 for model (3).

INSERT TABLE 7 ABOUT HERE

Models (1A) and (3A) in Table 7 correspond to the sets of regressors used in (1) and (3) in Table 2 with the exception that the spline variable has been added. The coefficient on the spline variable is marginally significant for specification (1A). This result indicates that unionization has large and negative marginal effects on R&D expenditure rates at union rates below 0.48, with smaller but still negative marginal effects above this point. In other words, a 1% increase in unionization continues to reduce R&D as the base level of unionization rises, but possibly at a diminishing rate. For model (3A), the results are similar in flavor, but the spline term is closer to being significant at 5%. Overall, the spline results provide some weak evidence in favor of the hypothesis that unionization has its largest marginal impact on R&D rates at low levels. These findings of a non-linearity are similar to findings in the literature on unions' effect on investment in physical capital, such as Hirsch (1991, 1992) and in a Canadian context Odgers and Betts (1997).

How big are the estimated effects of unionization on R&D spending rates? The results from Table 2 indicate that unions have a large and significant negative effect on R&D investment rates with all coefficients less than -0.0499, whereas the mean value for the R&D investment rate is only 0.023. This implies that an industry going from a unionization rate of zero to the mean rate of unionization (0.424) would have at least a 47.9% percent reduction in R&D expenditure rates.[17] The range of estimates from Table 2 is a drop in R&D of 47.9% to 50.3%, with the highest estimate deriving from (1). The estimates in Table 3 suggest that R&D rates would fall by 48.6-51.1% if an industry moved from zero unionization to the mean rate in the sample. In the outlier specifications, the union effect was smallest when we excluded Electrical Products. The coefficients estimated in regression (1C) from Table 6 together with the sample averages for R&D expenditure rates and unionization rates with Electrical Products excluded (0.0170 and 0.433 respectively) indicate that R&D expenditure rates are about 28.8% lower for an industry with the mean level of unionization than for a similar nonunion industry. So even here the estimated effects are large. Finally, in the spline models in Table 7, due to the large coefficient on the main unionization variable, the predicted drop when an industry changes from zero to mean unionization rates is 60.2% and 60.3% for models (1A) and (3A) respectively. But given that in neither model was the spline variable significant at conventional levels, the more conservative estimates from the linear models in Table 2 may be more reliable.

Of course, these estimates extrapolate beyond the support of the data – the lowest level of unionization observed in the sample is 0.119, not 0. Perhaps a more reasonable way of estimating the importance of unionization on R&D is to calculate the impact of an interquartile change in unionization on R&D. Table 8 reports the relevant interquartile ranges for the given sample, and the predicted effect of an interquartile increase in unionization, expressed as a percentage of the predicted R&D rate in the given sample if unionization is at the 25th percentile. The baseline model, in Table 2 model (1), suggests that an interquartile rise in unionization leads to a 41.9% decline in R&D rates. This figure is close to the estimated effect of switching form a zero-union industry to an industry with average unionization.[18]

INSERT TABLE 8 ABOUT HERE

The spline model, with its non-linear effect of unionization on R&D, predicts a 56.5% drop in R&D with an interquartile rise in unionization. Other specifications, as shown in Table 8, tend to show similar results. (The models that weight by GDP and that exclude the electrical products industry lead to the highest and lowest predicted drops in R&D, respectively, of 66.0% and 21.6%.) The simple average of predicted effects in Table 8 is a decline in R&D of 43.7%. Overall, Table 8 suggests that the impact of unions on R&D, by any standard, is large.

5. CONCLUSION

This paper finds supporting evidence for the hypothesis that union rent-seeking reduces R&D investment. In the industries that had consistent data available for all series used in this paper (primarily manufacturing and natural resource industries), an industry having an average unionization rate suffers a reduction in R&D expenditure rates of between 28-50%.[19] Such estimates are possibly inaccurate because no industry in our sample ever had unionization of zero. Perhaps more meaningfully, in our leading specification an interquartile rise in unionization is predicted to cause R&D to decline by about 40%. These results bear a strong resemblance to those of Hirsch (1990,1992) and others which find that in the United States unions reduce R&D investment rates. However, the effects found here are larger in magnitude than those using U.S. data. Studies using U.S. data find that unions reduce R&D expenditures by 11-32%. In part, these differences may simply reflect higher levels of unionization, and therefore a larger overall impact, in Canada.[20] But the larger impact of unionization on R&D expenditures in Canada may also result from Canadian law that is more favorable to unions. More favorable labor laws may increase the unions' bargaining power for any given level of unionization. In addition to finding that unions have a negative impact on investment, the results provide weak evidence that the union effect is non-linear, with unionization having marginal effects which are still negative but smaller, at high levels of unionization.

These results strongly confirm the earlier American literature. At the same time, our results also strengthen earlier work in that we identify the impact of unionization on R&D using variations in unionization within each industry over time, rather than using cross-sectional variations. The estimated impact of unionization on investment rates in R&D appears to be negative and very large on both sides of the Canada-United States border.

APPENDIX I
DATA SOURCES

Information on the number of union members by industry is collected annually by the Canadian Federal government, under the Corporations and Labour Unions Returns Act. Union membership data from 1970 and later were taken from the publications “Corporations and Labour Unions Returns Act Part II -- Labour Unions”, and information for earlier years was taken from “Corporations and Labour Unions Returns Act: Report”.

Information on research and development expenditures and price indexes for 1963-87 were obtained from Statistics Canada’s “Price Indexes For Canadian Industrial Research and Development Expenditures”, Catalogue ST-92-01.

Data on book profit before taxes and income taxes paid by industry for 1965-87 were obtained from annual editions of Statistics Canada's "Corporation Taxation Statistics", Catalogue 61-208.

Information on imports, exports, sales, GDP, employment and wages by industry was obtained from the University of Toronto's DSS/OCIB input-output database. This database is derived from the input-output tables published by Statistics Canada. (See Fujimagari, 1990 for information.)

Herfindahl indices at the 4-digit SIC level, based on the value of shipments for each enterprise, were obtained from Statistics Canada on disk. Industry aggregation was accomplished by weighting with industry value of shipments provided on disk; however, Herfindahl data was unavailable for two industry components (agriculture and fishing & trapping) of industry 2 (See Table 1 for industry components of industry 2). It is not expected that these industries have significant concentration. Therefore, a Herfindahl index value of zero was assigned to both industries. Since Herfindahl data were unavailable for (agriculture and fishing & trapping), these industries have missing values for industry shipments. Therefore, the value for industry output obtained from the input-output tables were used as the aggregating weights for these industries.

Industries were aggregated as necessary to obtain a consistent set of definitions across data sources. Aggregation of a group of industries in general involved simple summation of each variable, but for non-additive variables care was devoted to obtaining meaningful aggregate measures.

BIBLIOGRAPHY FOR DATA SOURCES

Fujimagari, David (1990), “The DSS/OCIB Input-Output Database”, Technical Study # 90-1, Institute for Policy Analysis, University of Toronto.

Statistics Canada (various years), “Corporation Taxation Statistics”, Catalogue 61-208, Ottawa: Statistics Canada. (Published by Dominion Bureau of Statistics until 1968.)

Statistics Canada (various years), “Corporations and Labour Unions Returns Act Part II -- Labour Unions”, Catalogue 71-202, Ottawa: Statistics Canada.

Statistics Canada (various years), “Corporations and Labour Unions Returns Act: Report”, Ottawa: Statistics Canada.

Statistics Canada (February 1992), “Price Indexes for Canadian Industrial Research and Development Expenditures”, Ottawa: Statistics Canada.

APPENDIX II: Calculation of American R&D Rates by Year and Industry

Data on annual R&D spending were obtained from National Science Foundation publications, and were put into real terms using the GDP deflator, as obtained from Citibank's Economic Database.

A number of minor inconsistencies arise between the industry definitions available in the United States and Canada. The Canadian data includes two industries, Mining, Quarries and Oil Wells and Nonmetallic Minerals, which were not included in the United States R&D data. These industries were dropped in any regressions that conditioned on American R&D. Tobacco is not included with Food and Beverage in U.S. until after 1984, before which it was included in Other Manufacturing. Lumber and Wood include furniture in the U.S. but furniture is included in Other in Canada. U.S. Transportation includes missiles. For Canada "Other Manufacturing" included leather, textiles, knitting, clothing, furniture, printing, scientific equipment, rubber, plastics, and other miscellaneous manufacturing. In the United States "Other Manufacturing" included rubber products, professional and scientific equipment, textiles and apparel, and other manufacturing industries.

Because of missing data on R&D spending in some industry/year combinations, missing data were imputed by linear interpolation. Specifically, we interpolated data for Food and Beverage for 1981-1986, for Tobacco for the same period, for Paper in 1981, and 1983-1986, for Primary Metals from 1984-1986, for Machinery in 1986, for Other Manufacturing in 1981-1985, for Textiles in 1981-1986, for Business Machines in 1968-1971 and 1981-1986, and for Rubber in 1981-1986.

In addition, we extrapolated for Business Machine GDP for 68-76.

BIBLIOGRAPHY FOR U.S. DATA SOURCES

National Science Foundation, Research and Development in Industry: 1994, NSF 97-331, Detailed Statistical Tables, available in paper copy and on diskette (Washington, D.C., 1997).

National Science Foundation, Research and Development in Industry: 1991, NSF 94-325, Detailed Statistical Tables, available in paper copy and on diskette (Washington, D.C., 1994).

National Science Foundation, Research and Development in Industry: 1988, NSF 90-319, Detailed Statistical Tables, available in paper copy and on diskette (Washington, D.C., 1990).

National Science Foundation, Research and Development in Industry: 1983, NSF 85-325, Detailed Statistical Tables, available in paper copy and on diskette (Washington, D.C., 1985).

National Science Foundation, Research and Development in Industry: 1979, NSF 81-324, Detailed Statistical Tables, available in paper copy and on diskette (Washington, D.C., 1981).

National Science Foundation, Research and Development in Industry: 1977 NSF 79-325, Detailed Statistical Tables, available in paper copy and on diskette (Washington, D.C., 1979).

CITIBASE: CITIBANK ECONOMIC DATABASE, 1946- OCT, 1992 [Computer file]. New York: Citibank, N.A., [distributor], 1992.

TABLE 1 Industry Regressions

Industry	Constant	Union Rate
1. Mining, Quarries and Oil Wells	0.0079	-0.0097
	(3.39)	(-1.79)
2. Food & Beverages,Tobacco,	0.0197	0.0029
	(3.89)	(0.90)
3. Petroleum & Coal Products	0.1155	-0.1883
	(3.77)	(-1.11)
4. Chemicals	-0.0144	.1990
	(-1.51)	(4.96)
5. Wood & Forestry	0.0034	-0.0040
	(1.82)	(-1.03)
6. Paper	0.0152	-0.0101
	(3.15)	(-1.53)
7. Primary Metals	0.0121	-0.0064
	(2.35)	(-0.82)
8. Metal Fabricating	0.0053	-0.0048
	(3.90)	(-1.46)
9. Machinery	0.0230	0.0127
	(6.53)	(1.51)
10. Transportation Equipment	0.0735	-0.0728
	(4.32)	(-2.64)
11. Electrical Products	0.3010	-0.4515
	(7.75)	(-5.31)
12. Nonmetallic Minerals	0.0082	-0.0090
	(1.86)	(-1.07)
13. Other Manufacturing	0.0176	-0.0374
	(8.96)	(-6.74)

TABLE 2 Models with Industry Fixed Effects

Note: Mean R&D rate in the sample is 0.023. Number of observations is 247.

	(1)	(2)	(3)	(4)
Constant	0.000771	-0.000762	-0.002511	-0.004549
	(0.09)	(-0.10)	(-0.30)	(-0.57)
Union Rate	-0.054803	-0.052043	-0.053498	-0.049911
	(-3.84)	(-4.01)	(-3.75)	(-3.82)
Import Share	0.064231	0.062468	0.067325	0.065105
	(3.01)	(2.91)	(3.26)	(3.14)
Growth4	-0.008920	-0.007973	-0.009145	-0.007926
	(-1.67)	(-1.48)	(-1.78)	(-1.55)
Herfindahl	-0.023439	-0.019765	-0.013277	-0.008351
	(-0.44)	(-0.38)	(-0.26)	(-0.17)
Profit Rate			0.021526	0.021915
			(1.30)	(1.32)
Time Trend		0.000105		0.000136
		(0.88)		(1.07)
R-Squared	0.883599	0.883848	0.888681	0.889094
Adjusted R-Sq	0.875502	0.875225	0.880417	0.880339
Durbin-Watson	0.493438	0.486114	0.500410	0.490992
White Het. (P-Val)	0.143	0.019	0.000	0.000
P-Val Pool vs FE	0.000	0.000	0.000	0.000

TABLE 3 Models With Industry Random Effects

Note: Number of observations is 247.

	(1’)	(2’)	(3’)	(4’)
Constant	0.026256	0.024034	0.019982	0.017012
	(2.37)	(2.10)	(1.92)	(1.58)
Union Rate	-0.056742	-0.053918	-0.054949	-0.051288
	(-4.13)	(-3.79)	(-4.11)	(-3.71)
Import Share	0.059123	0.057304	0.062244	0.059974
	(5.13)	(4.87)	(5.55)	(5.25)
Growth4	-0.009076	-0.008022	-0.009347	-0.007976
	(-2.09)	(-1.76)	(-2.20)	(-1.79)
Herfindahl	0.000986	0.004198	0.009033	0.013102
	(0.02)	(0.09)	(0.19)	(0.28)
Profit Rate			0.023645	0.024073
			(3.61)	(3.67)
Time Trend		0.000116		0.000151
		(0.78)		(1.03)
R-Squared	0.876144	0.876427	0.880829	0.881298
Adjusted R-Squared	0.867528	0.867254	0.871983	0.871926
P-Val R.E. vs. F.E.	0.2312	0.2405	0.2242	0.2378

TABLE 4 Models That Control for R&D in the United States, with Industry Random Effects

Note: Number of observations is 209.

	(1)	(2)	(3)	(4)
Constant	0.032980	0.030955	0.026283	0.023502
	(2.72)	(2.51)	(2.25)	(1.98)
Union Rate	-0.066382	-0.063723	-0.063815	-0.060370
	(-4.02)	(-3.81)	(-3.97)	(-3.70)
R&D Intensity U.S.	-0.034543	-0.047411	-0.012985	-0.028535
	(-0.63)	(-0.84)	(-0.24)	(-0.52)
Import Share	0.055657	0.053351	0.057118	0.054258
	(4.27)	(4.02)	(4.49)	(4.20)
Growth4	-0.012463	-0.011146	-0.014063	-0.012413
	(-2.14)	(-1.86)	(-2.45)	(-2.11)
Herfindahl	0.031355	0.037943	0.033863	0.042215
	(0.57)	(0.68)	(0.63)	(0.78)
Profit Rate			0.025166	0.025842
			(3.45)	(3.54)
Time Trend		0.000168		0.000215
		(0.94)		(1.23)
R-Squared	0.101661	0.098245	0.230714	0.237343
Adjusted R-Sq	0.079534	0.071460	0.207864	0.210783
Durbin-Watson	0.065510	0.064396	0.076019	0.074944
P-Val R.E. vs. F.E.	0.184000	0.184300	0.306900	0.318500

TABLE 5 Weighted Least Square Models with Industry Fixed Effects

Notes: Weight used is real GDP. Number of observations is 247.

	(1)	(2)	(3)	(4)
Constant	0.000327	-0.002283	-0.003855	-0.006249
	(0.05)	(-0.40)	(-0.58)	(-0.98)
Union Rate	-0.047732	-0.043220	-0.044950	-0.040745
	(-3.90)	(-3.81)	(-3.75)	(-3.66)
Import Share	0.054497	0.052991	0.058799	0.057314
	(3.08)	(3.02)	(3.27)	(3.21)
Growth4	-0.004334	-0.003089	-0.003131	-0.001977
	(-1.76)	(-1.19)	(-1.39)	(-0.81)
Herfindahl	0.030890	0.031074	0.037289	0.037364
	(0.71)	(0.74)	(0.88)	(0.91)
Profit Rate			0.018314	0.018035
			(1.71)	(1.70)
Time Trend		0.000134		0.000126
		(1.78)		(1.67)
R-Squared	0.881558	0.881812	0.886141	0.886510
Adjusted R-Sq	0.873318	0.873038	0.877688	0.877550
Durbin-Watson	0.589088	0.584653	0.572487	0.568021

TABLE 6 Outlier Specifications

Note: Number of observations in the full sample is 247. Model 1A excludes 4 observations, 1B excludes the chemical industry, 1C excludes the electrical products industry, and 1D excludes both the chemical and electrical industries.

	1A	1B	1C	1D
Constant	0.004126	0.002338	0.015829	0.016969
	(0.57)	(0.27)	(2.96)	(3.12)
Union Rate	-0.049295	-0.060611	-0.015904	-0.021759
	(-3.44)	(-4.18)	(-2.02)	(-2.81)
Import Share	0.051482	0.065508	-0.010381	-0.007922
	(2.63)	(3.08)	(-0.76)	(-0.58)
Growth4	-0.010335	-0.009260	-0.014328	-0.014741
	(-1.98)	(-1.68)	(-2.94)	(-2.94)
Herfindahl	-0.043655	-0.019508	-0.010047	-0.005967
	(-0.75)	(-0.36)	(-0.30)	(-0.18)
R-Squared	0.884019	0.888539	0.895151	0.898548
Adjusted R-Squared	0.875808	0.880653	0.887732	0.891227
Durbin-Watson	0.698185	0.642544	0.949026	0.928459
White Het. (P-Val)	0.079000	0.192000	0.743000	0.767000
Observations	243	228	228	209

TABLE 7 Spline Estimation

	1A	3A
Constant	0.011956	0.009371
	(1.02)	(0.81)
Union Rate	-0.081883	-0.082364
	(-3.07)	(-3.10)
Union Spline Term	0.054053	0.057657
	(1.71)	(1.80)
Import Share	0.059820	0.062667
	(2.84)	(3.07)
Growth4	-0.008510	-0.008711
	(-1.59)	(-1.71)
Herfindahl	-0.017649	-0.006948
	(-0.34)	(-0.14)
Profit Rate		0.021851
		(1.32)
Union Rate at Which Knot Occurs	0.48	0.48
R-Sq	0.884693	0.889925
Adj. R-Sq	0.876133	0.881234
Durbin-Watson	0.479893	0.481717
White Het.(P-Val)	0.329	0.000

TABLE 8 Estimates of Predicted Drop in R&D Rate with an Interquartile Increase in Unionization, Calculated as a Percentage of Predicted R&D Rate at the 25th Percentile Level of Unionization in Subsample

Sample and Model	Description	Interquartile Range	Predicted % Change in R&D Rate
Table 2 (1)	Baseline Model, Full Sample	0.226168	-41.9%
Table 3 (1')	Random Effects, Full Sample	0.226168	-43.0%
Table 4 (1)	Random Effects, Subsample with U.S. Data	0.303746	-53.5%
Table 5 (1)	Weighted Least Squares, Full Sample	0.294681	-66.0%
Table 6 (1A)	Without 4 Outliers	0.226366	-41.1%
Table 6 (1B)	Without Chemical	0.261213	-43.3%
Table 6 (1C)	Without Electrical	0.198173	-21.6%
Table 6 (1D)	Without Electrical, Chemical	0.219433	-26.7%
Table 7 (1A)	Spline Model, Full Sample	0.226168	-56.5%

Figure 1 R&D and Unionization Rates for Each Industry-Year Combination

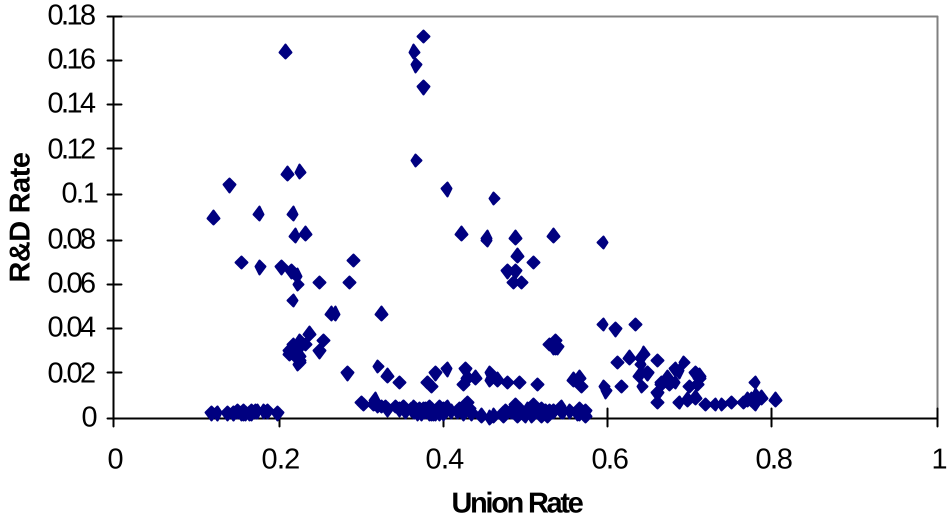


Figure 2 Nineteen-Year Changes in R&D and Unionization Rates for Each Industry, 1968-1986

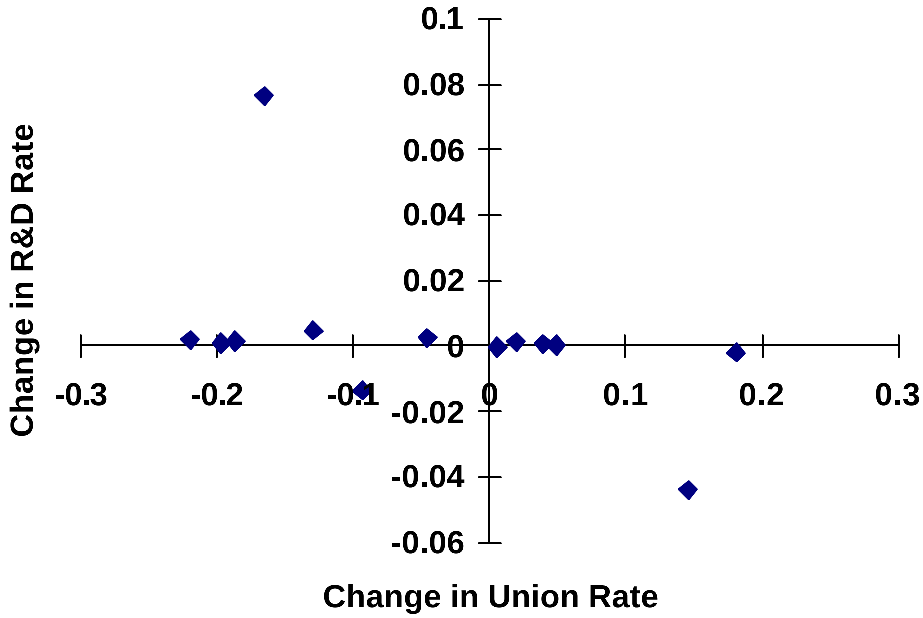


Figure 3 Mean R&D Rate by Year Versus Mean Union Rate by Year, with Simple Means Taken across Industries

Note: The mean R&D rate is multiplied by 20 to make the scale comparable to the union rate scale.

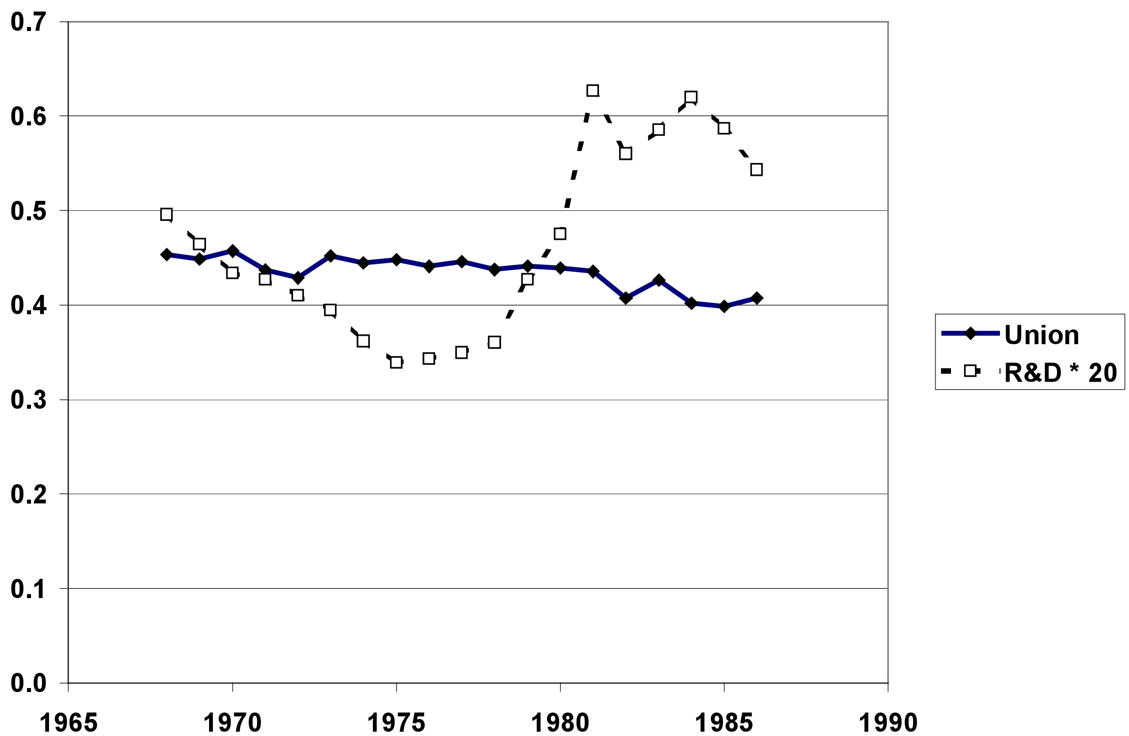


Figure 4 Mean R&D Rate by Year Versus Mean Union Rate by Year, with Means Weighted by Real GDP across Industries

Note: The mean R&D rate is multiplied by 20 to make the scale comparable to the union rate scale.

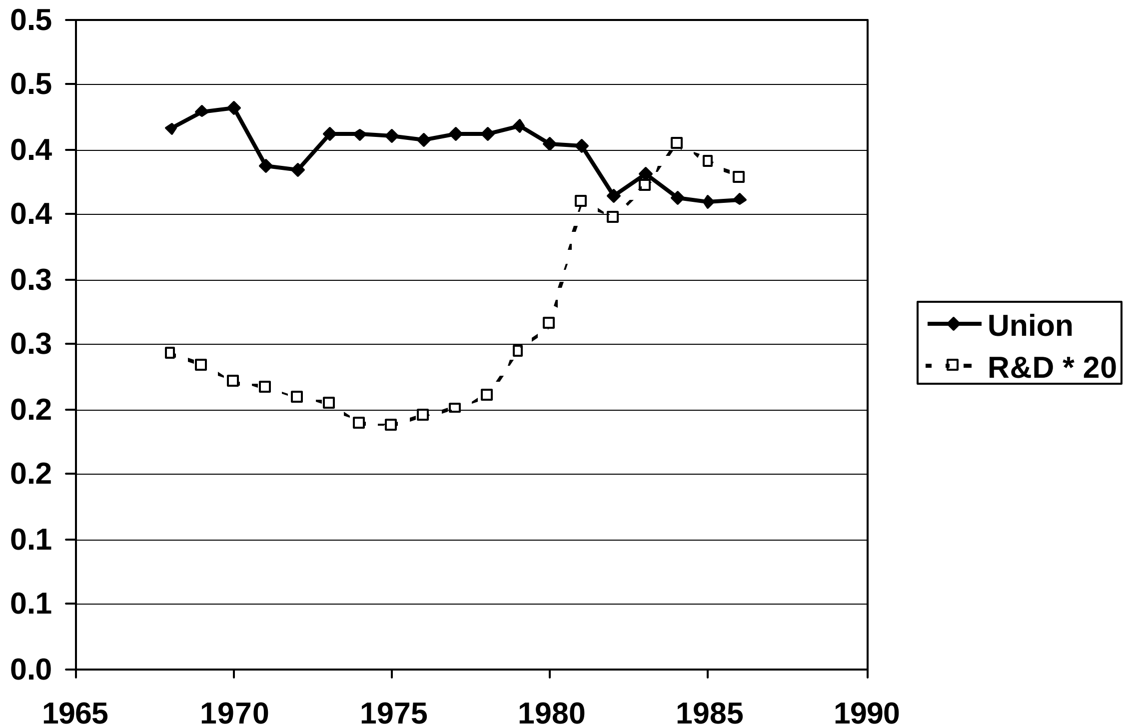
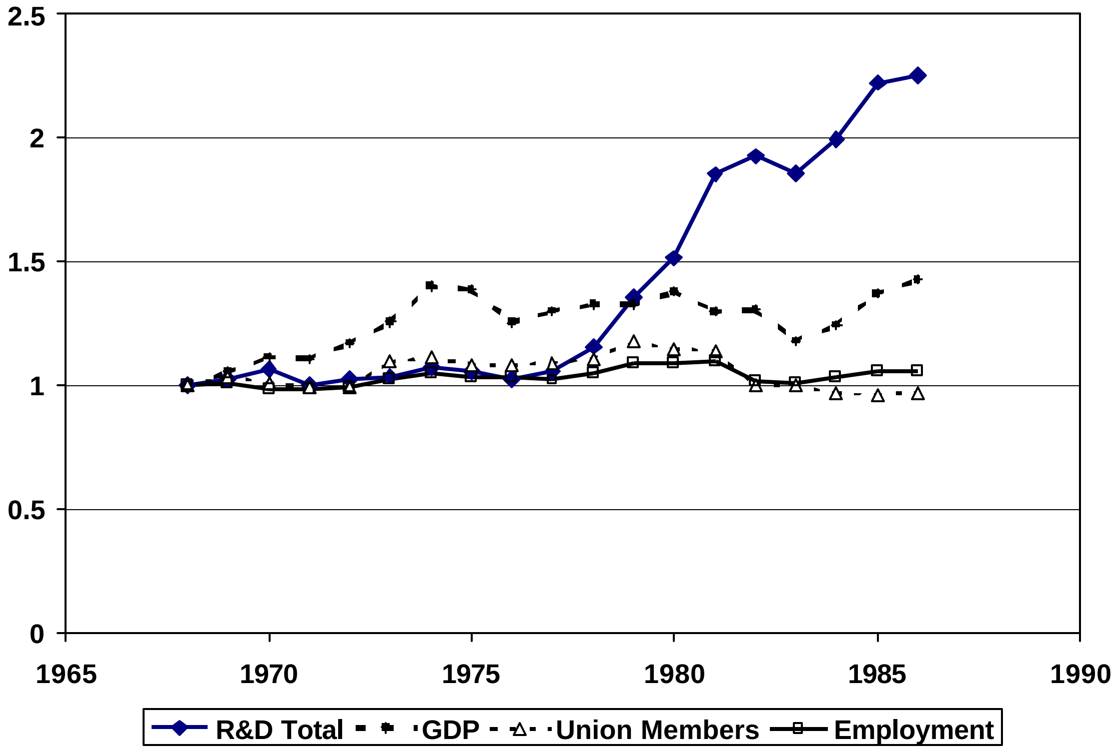


Figure 5 Means across Industries of Total R&D, GDP, Union Membership and Employment, by Year



References

Addison, J.T., and J. Wagner (1994) 'UK unionism and innovative activity: some cautionary remarks on the basis of a simple cross-country test,' *British Journal of Industrial Relations* 32, 85-98

Ashenfelter, O.C., and G.E. Johnson (1969) 'Bargaining theory, trade unions, and industrial strike activity,' *American Economic Review* 59, 35-49

Baldwin, C.Y. (1983) 'Productivity and labor unions: an application of the theory of self-enforcing contracts,' *Journal of Business* 56, 155-85

Belsley, D., E. Kuh, and R.E. Welsch (1980) *Regression Diagnostics* (New York: John Wiley & Sons)

Bronars, S.G., and D.R. Deere (1994) 'Unionization and profitability: evidence of spillover effects,' *Journal of Political Economy* 102, 1281-1287

Bronars, S.G., D.R. Deere, and J.S. Tracy (1994) 'The effects of unions on firm behavior: an empirical analysis using firm-level data,' *Industrial Relations* 33, 426-451

Connolly, R. A., B.T. Hirsch, and M. Hirschey (1986) 'Union rent seeking, intangible capital, and market value of the firm,' *Review of Economics and Statistics* 68, 567-577

Crawford, V. (1988) ‘Long-term relationships governed by short-term contracts,’ *American Economic Review* 78, 485-499

Cringely, R.X. (1992) *Accidental empires: how the boys of Silicon Valley make their millions, battle foreign competition, and still can’t get a date* (Reading, MA: Addison-Wesley Publishing Company)

Fallick, B.C., and K.A. Hassett (1999) ‘Investment and Union Certification,’ *Journal of Labor Economics* 17, 570-582

Freeman, R.B. (1992) ‘Is declining unionization of the U.S. good, bad, or irrelevant?’ in *Unions and Economic Competitiveness*, eds. L. Mishel and P.V. Voos (Armonk, New York: M.E. Sharpe)

Fujimagari, D. (1990) ‘The DSS/OCIB input-output database,’ *Technical Study # 90-1* (Institute for Policy Analysis, University of Toronto)

Grout, P.A. (1984) ‘Investment and wages in the absence of binding contracts: a Nash bargaining approach,’ *Econometrica* 46, 449-60

Hirsch, B.T. (1990) ‘Innovative activity, productivity growth, and firm performance: are labor unions a spur or a deterrent?’ *Advances in Applied Micro-Economics* 5, 69-104

Hirsch, B.T. (1991) *Labor Unions and The Economic Performance of Firms* (Kalamazoo, Michigan: W.E. Upjohn Institute for Employment Research)

Hirsch, B.T. (1992) 'Firm investment behavior and collective bargaining strategy,' *Industrial Relations* 31, 95-221

Menezes-Filho, N., D. Ulph, and J. Van Reenen (1998) 'R&D and unionism: comparative evidence from British companies and establishments,' *Industrial and Labor Relations Review* 52, 45-63

National Science Foundation (various years) *Research and Development in Industry* (Washington, D.C.).

Newey, W., and K.D. West (1987) 'A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix,' *Econometrica* 55, 703-706

Odgers, C.W. and J.R. Betts (1997) 'Do unions reduce investment? Evidence from Canada,' *Industrial and Labor Relations Review* 51, 18-36

Riddell, W.C., (1993) 'Unionization in Canada and the United States: a tale of two countries,' In *Small Differences that Matter: Labor Markets and Income Maintenance in Canada and the United States*, ed. D. Card and R.B. Freeman (Chicago: The University of Chicago Press)

Rosen, S. (1969) ‘Trade union power, threat effects and the extent of organization.’ *Review of Economics and Statistics* 36, 185-196

Statistics Canada (February 1992) *Price Indexes for Canadian Industrial Research and Development Expenditures* (Ottawa: Statistics Canada)

Van der Ploeg, F. (1987) ‘Trade unions, investment, and employment: a non-cooperative approach,’ *European Economic Review* 31, 477-501

Footnotes

Footnote 1. Typically capital and investment refer to physical capital and investment. However, from the rent-seeking perspective the important issues are the time span during which rents accrue to investment and the degree of firm specificity of investment. The more firm-specific the investment and the longer rents accrue the more vulnerable the quasi-rents are to capture by the union.

Footnote 2. See Odgers and Betts (1997) for a more thorough discussion of the theoretical aspects of the union rent-seeking model which applies to both investment in R&D and physical capital investment. Only those aspects which are more relevant to R&D investment will be discussed here.

Footnote 3. A classic example of how patenting an invention may in fact encourage competitors to copy the idea comes from the computer industry. IBM, when it established the market for personal computers in the early 1980's, used generic parts for the IBM PC, but relied on a copyrighted BIOS (Basic Input/Output System) chip to prevent imitators from entering the market. This legal protection did not protect IBM from Compaq and others who successfully copied the functions of the chip, almost instantly removing IBM's monopoly. See Cringely (1992) for an entertaining account.

Footnote 4. We calculated this using column 1 of Table 3 in their paper. The predicted drop in R&D was divided by the sum of the actual sample average for R&D and the predicted gain in R&D that would have resulted with zero unionization. This approach yields the predicted proportional drop in R&D had the economy started with no union members. The authors argue that the overall effect may have been larger if they had not conditioned R&D upon the excess market value of the firm, since they find that this variable declines as unionization rises, and that R&D rises with excess valuation.

Footnote 5. This figure is based on column 4 of Table 5 in Hirsch (1992), using the coefficient for the 'total' sample.

Footnote 6. In Odgers and Betts (1997) there are 18 manufacturing industries represented in the sample. For this paper the most detailed aggregation allowed by the R&D expenditures data set was used. A further aggregation was necessary as data on R&D expenditures were not consistent with the aggregation of the other data sets (e.g., food and beverages, tobacco, agriculture, and fishing and trapping can be obtained as separate industries for all variables apart from R&D expenditures). The result is slightly fewer aggregate industries.

Footnote 8. Two American studies use a short panel to investigate the impact of union certification at the firm level -- Bronars and Deere (1994) and Fallick and Hassett (1999). Neither paper studies R&D.

Footnote 9. There are two different prices indexes used. R&D expenditures have a specialized price index which measures R&D price changes based on changes in input prices used in the R&D process (see Statistics Canada, 1992, for details). This differs from the GDP implicit deflator which is an output based measure of price changes. The real value of GDP is calculated using the GDP deflator.

Footnote 10. The import share is calculated as imports divided by total output less net exports. The profit rate is calculated as real profits divided by real GDP. Real profits are calculated as nominal book profits less taxes, all divided by the economy-wide GDP deflator. In all of the regressions, the lagged profit rate is used to reduce the potential for simultaneity bias in specifications which use it as a regressor, and also to capture the notion of a decision lag between the time when profits are revealed and the time when R&D expenditures are planned. The Herfindahl index is the sum of the squared market share for each firm. Thus a value near zero indicates little industry concentration, whereas a value of one indicates monopoly.

Footnote 11. Most of the observations with R&D expenditure rates above 0.12 are from the electrical products industry.

Footnote 12. We also plotted these four trends using averages across industries that were weighted by industry GDP. Little changes in this analysis.

Footnote 13. See Hirsch (1990,1992) for results illustrating this possibility.

Footnote 14. Models with up to five lag terms were estimated, all with similar results.

Footnote 15. Note also that the t-statistics are much larger in absolute value for the random effects coefficients attached to the profit and import share variables than for the fixed effects coefficients.

Footnote 16. We thank an anonymous referee for this suggestion.

Footnote 17. Observations with high leverage were identified as recommended in Belsley, Kuh, and Welsch (1980). On average the diagonals of the "hat" matrix have a value equal to k/n where k is the number of regressors and n is the sample size. Diagonals with a value greater than 2k/n are identified as high leverage observations.

Footnote 18. To obtain the percent reduction in R&D rates, we first multiply the coefficient on the union variable by the mean level of unionization. We subtract the result from the mean R&D expenditure rate to derive the predicted R&D rate for a nonunion industry. The difference between the mean R&D rate and the predicted R&D rate for a nonunion industry, multiplied by 100 and then divided by the predicted nonunion R&D rate gives the percentage reduction.

Footnote 19. Even though the interquartile change in unionization is about half the change used in the "Zero-to-average-unionization" simulation, the denominator in the present simulation is predicted R&D if unionization density is at the 25^{th} percentile, not the predicted R&D rate at 0 unionization, as in the former case. These two changes in the nature of the simulation work in opposite directions. For this reason, the two apparently dissimilar scenarios of increasing unionization in the end produce similar estimated changes in R&D.

Footnote 20. The lower value was obtained from the estimate with Electrical Products excluded from the sample.

Footnote 21. For instance, in the data-set used by Connolly, Hirsch and Hirschey (1986), mean unionization was 39.1%. In the data-set compiled by Hirsch (1991) mean unionization was 33.3%. In contrast the average unionization rate was 42.4% in our Canadian data-set.