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THE IMPACT OF U.S. UNIONS ON PRODUCTIVITY: A BOOTSTRAP META-ANALYSIS

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Abstract

Resampling methods are used to calculate confidence limits in a meta-analysis of the association between unions and productivity for the population of U.S. studies. The available evidence points to a positive and statistically significant association between unions and productivity in the U.S. manufacturing and education sectors, of around 10% and 7%, respectively.

THE IMPACT OF U.S. UNIONS ON PRODUCTIVITY: A BOOTSTRAP META-ANALYSIS

1. Introduction

Meta-analysis has been developed to facilitate a *quantitative* research synthesis (Hunter and Schmidt 1990). Meta-analysis uses empirical studies as the basic unit of analysis. Measures such as elasticities are derived from all the available studies and descriptive statistics such as averages are calculated for all studies and for groups of studies. Confidence intervals can be constructed to investigate whether an estimated association is statistically significant. There is now a rapidly growing body of applications of meta-analysis to economics (see Stanley 2001).

One of the problems with the construction of confidence intervals in meta-analysis is that the distribution of the studies is unknown and may not be normal. Adams *et al.* (1997) have shown that resampling techniques can be used to construct bootstrap confidence intervals in meta-analysis. This technique has not been used in any of the economics meta-analysis studies.

In this paper, the bootstrap is applied to a meta-analysis of the U.S. union-productivity effects literature. Union-productivity effects continue to be one of the most controversial issues in economics. Theory has postulated a number of channels through which unions may increase or decrease productivity. The *net* impact of unions on productivity is an empirical issue (see Kuhn 1998). Meta-analysis is ideal in this situation as it enables inferences to be drawn from the pool of available studies.

2. The Bootstrap and Meta-analysis

The bootstrap is applied normally to statistics derived from a *single* sample. In meta-analysis the statistics are derived from data that are drawn from numerous studies, involving different datasets. However, resampling techniques can be used to estimate standard errors and confidence intervals for any test statistic (see Efron and Tibshirani 1993, Shao and Tu 1995 and Adams *et al.* 1997). The underlying population will include published studies, unpublished studies, and results that never migrated beyond the estimation stage. If the published studies are representative of the underlying population of studies, then resampling from observed studies will imitate the process of sampling observations from the population of studies.

In a typical bootstrap application, each observation is assigned an equal weight. However, in meta-analysis, larger studies should be given more weight, as smaller samples will have larger variances and will thus be less precise. A number of weights are possible, such as sample size, number of citations and journal ranking. The normal approach in meta-analysis is to use sample size (see Hunter and Schmidt 1990).

3. Procedure and Results

Doucouliagos and Laroche (2003) identify 53 US union-productivity studies, which we use for our meta-analysis. The measure of interest is the *total* productivity differential between unionized and non-unionized firms. Bootstrapping was undertaken using 1000 iterations (with replacement) from which the distribution of U.S. union-total productivity effects were generated. The percentile method was used to construct bootstrap confidence intervals (see Efron and Tibshirani 1993). The lower and upper 2.5 percent of the values of the generated distribution are used to construct the 95 percent confidence intervals. The bootstrap confidence intervals so created are centered on the observed data.

The bootstrap confidence intervals (BCI) can be compared to normal meta-analysis confidence intervals. There are a number of ways in which confidence intervals are constructed in meta-analysis (for examples see Hedges and Olkin 1985 and Hunter and

Schmidt 1990). However, these are all based on large samples and assume that the meta-analysis test statistics are asymptotically normally distributed.

Confidence intervals used in meta-analysis are constructed usually around weighted effect sizes, with the sample size used as the weight. The weighted confidence intervals (WCI) are given by:

$$WCI = \overline{P}_k \pm t_{\alpha/2} * s_{\overline{P}k} \tag{1}$$

$\overline{P}_k$ is the estimated weighted average union-productivity effect from a set of *k* studies and is calculated as $\overline{P}_k = \frac{\sum_{i=1}^{k} w_i P_i}{\sum_{i=1}^{k} w_i}$, where w_i is the sample size of study i. $s_{\overline{P}_k}$ is the variance of $\overline{P}_k$. Hedges and Olkin (1985) and Rosenberg *et al.* (2000) provide details on the statistical theory behind these intervals.

Sample size can be used also to assign weights to union-productivity effects when deriving bootstrap confidence intervals. Each study's union-productivity effect is adjusted by sample size and the bootstrap is then applied. We denote these as weighted bootstrap confidence intervals. Sample size weighted averages and confidence intervals are expected to be more accurate than unadjusted measures.

Confidence intervals were constructed for three sets of meta-analyses - for all studies, for studies organized chronologically and for specific industries. The results are presented in Table 1. The unweighted bootstrap confidence interval when all US studies are used includes zero (-0.4% to +14%), suggesting no association between unions and productivity. In contrast, the weighted confidence interval and the weighted BCI do not include zero (+5% to +13% and +4% and +15%, respectively).

Table 1: Union-Total Productivity Effects, U.S. Studies

Year Interval	K	N	Mean Effect (%)	Weighted Mean Effect (%)	BCI (%)	Weighted CI (%)	Weighted BCI
All Studies	53	47,469	+7	+9	-0.4 to +14	+5 to +13	+4 to +15
Chronological order							
< 85	9	10,616	+8	+2	+3 to +13	0 to +4	-1 to +9
85 < 90	17	2,828	+5	+24	-16 to +24	+20 to +28	+8 to +40
90 < 95	15	15,168	+10	+0.1	+1 to +19	-2 to +2	-5 to +11
95 < 02	12	18,857	+7	+2	0 to +16	+1 to +4	-2 to +12
Sub-groups							
Manufacturing	9	4,736	+10	+10	-14 to +26	+7 to +13	+3 to +26
Education	8	13,824	+9	+7	-3 to +25	+6 to +10	+0.1 to +17

K = number of studies, N = total sample size. BCI= bootstrap confidence interval. Sample size used as weights for weighed statistics.

Grouping the studies in chronological order illustrates the "evolution" of the findings in this literature. Interestingly, it is only the studies published between 1985 and 1990 that have a statistically significant positive union-productivity effect (+8% to +40%).

Separate listings are presented for those studies that explored the impact of unions on U.S. manufacturing and the productivity impact of U.S. teacher unions. For both industries, the weighted confidence interval and the weighted BCI do not include zero. The weighted and unweighted intervals lead to conflicting conclusions regarding the statistical significance of the estimated positive union-total productivity effect. For this dataset, the unweighted BCIs lead to an erroneous conclusion of no association between unions and productivity. This difference can be attributed to the influence of many studies with small sizes. For example, 60 percent of the studies that used a sample of 100 observations or less reported a negative union-productivity association. The use of weighted confidence intervals helps to remove the impact of this distortion.

We conclude that all the available evidence indicates that unions have a positive and statistically significant positive effect on productivity in U.S. manufacturing and education, of 10% and 7%, respectively. However, given that U.S. unions appear to increase wages by around 15% (see Kuhn 1998), there is a net negative impact on profitability.

Should the bootstrap be used to construct confidence intervals? One way to answer this is to examine Figure 1. This is a histogram of the replicated variances when all studies are used. If this is normally distributed then the bootstrap would not be the preferred approach. However, the histogram does not appear to follow the normal distribution. This can be seen more clearly through Figure 2, which is a quantile-quantile plot of the replicated variances. The straight line traces the standard normal distribution. It is clear that the two tails of the replicated variances distribution diverge from the normal distribution. This suggests that the bootstrap confidence intervals are preferable in the meta-analysis of union-productivity effects.

Figure 1: Replicated Variances Histogram

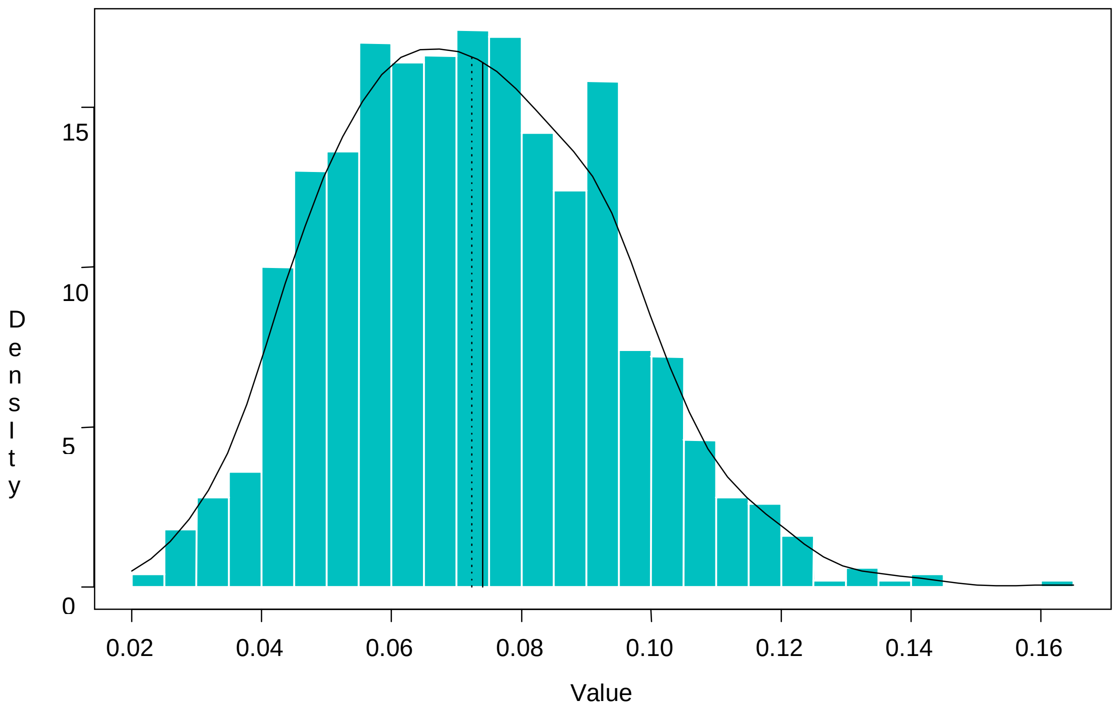
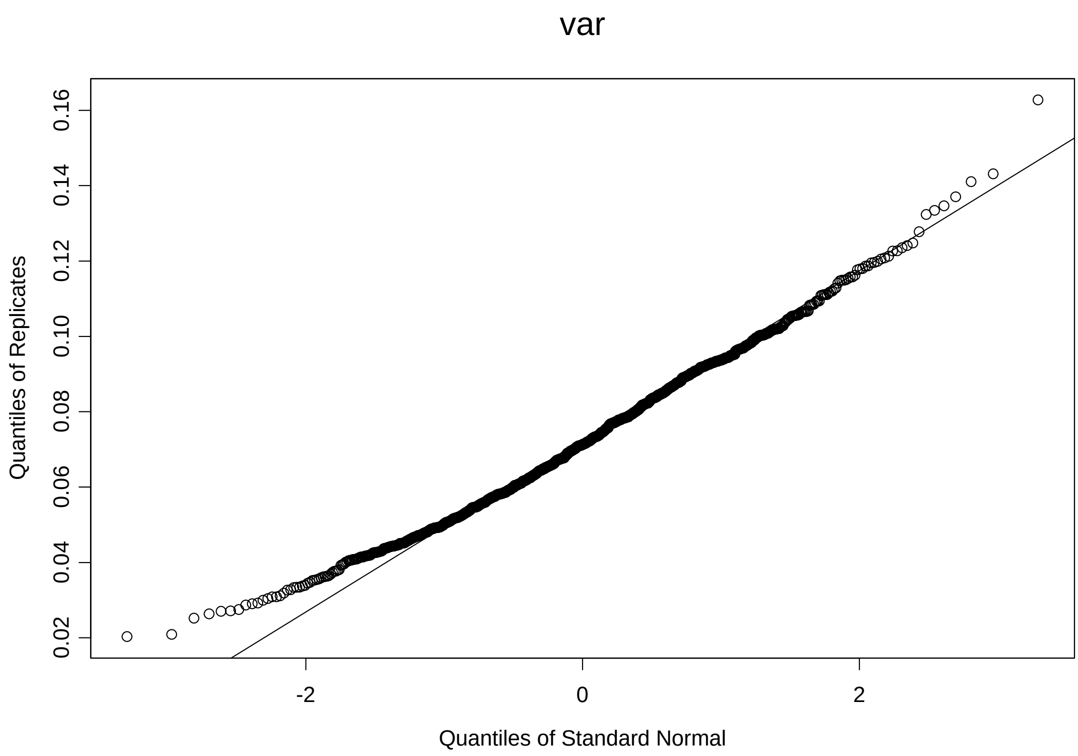


Figure 2: Quantile-Quantile Chart of Replicated Variances



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Appendix A: Studies included in the meta-analysis

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