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ABSTRACT

Unions and Innovation: A Survey of the Theory and Empirical Evidence*

This Paper surveys the economic literature on the impact of trade unions on innovation. There are many theoretical routes through which unions may have an effect on innovation, for example through their effects on relative factor prices, profitability and their attitudes towards the introduction of new technology. Recent theoretical work has focused on the possibility that trade unions will 'hold up' firms by expropriating sunk R&D (research and development) investments through demanding higher rewards. The hold up problem may be mitigated (or exacerbated) by strategic incentives to compete in R&D races. In an attempt to resolve the theoretical ambiguity we focus on surveying recent micro-econometric results in the areas of R&D, innovation, technological diffusion and productivity growth. North American results find consistently strong and negative impacts of unions on R&D. By contrast, European studies (mainly in the UK) generally do not uncover negative effects of unions on R&D. There is no consensus of the effects of unions on our other main measures: technological diffusion, innovation or productivity growth even in the North American studies. These cross-country differences in the R&D impact of unions could represent either unsolved econometric problems or genuine institutional differences between nations in union attitudes and ability to bargain. We suspect the latter is the main reason.

JEL Classification: J51, O31 and O32
Keywords: innovation, productivity growth, R&D and unions

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1. Introduction

The role of trade unions in the economy has always been the subject of intensive debate. Traditionally, the theoretical literature emphasized the role of unions in distorting relative prices and the empirical studies concentrated on the determinants of union membership and on the effect of unions on wages and profitability. More recently however, economists have focused on the role of unions as "taxing" the returns on sunk capital and on the design of efficient contracts, whereas applied economists shifted their attention to the long-term effects of unions, that is, on investment, technology and productivity growth.

The reason for this shift is clear. If the presence of strong unions led the firms to reduce capital and R&D (research and development) investments (and therefore reduced productivity growth) then unionised firms would tend to lose market share. In turn this would mean that the unionised sector would shrink and eventually trade unions would disappear from the economy[1]. In a closed economy unions could organize an entire industry in order to avoid withering away, but this option is unavailable in an open economy, where a unionised industry will be undermined by competition from countries with weaker unions[2]. Some commentators have contrasted the high R&D and dynamic innovation of the US (where unions are weak) with the relatively lower R&D and slower innovation of Europe (where unions are strong) and drawn the conclusion that unionised labour markets may be at the heart of Europe's problems. If, on the contrary, the presence of unions leads to increase in innovation and productivity (or are at least neutral), then their long-term prospects are brighter.

In this paper we will review the literature on the effects of unions on innovation. We will take a broad view of innovation and include both the key inputs to the innovation process - R&D expenditures – as well as the outputs of the "knowledge production function" - innovation, diffusion and finally, productivity growth. Moreover, we intend to carefully evaluate the literature outside the United States, where many of the previous surveys have concentrated. This survey will not address the 'macro' literature about institutions and performance (the reader is referred to Layard and Nickell, 1999, for a more detailed treatment). Nor will we look at unions and the diffusion of "managerial innovations" (such as decentralization and delayering).

The structure of the survey is the following. We start with a review of the papers that theoretically model the relationship between unions and firms. We then focus on empirical issues, such as measurement, aggregation and the econometric problems that arise when the researcher investigates the effects of unions on the different aspects of innovation. We proceed with a survey of the results of the papers that have estimated the impact of unions on R&D, innovation, technological diffusion and productivity growth. In the final section we offer some concluding remarks.

In short, the effects of unions on innovation are generally ambiguous both in theory and in empirical practice. There does, however, seem to be some emerging consensus that there is a negative association between unions and R&D in North America. This is not the case for Europe where no such relationship is found. We discuss reasons for this in the conclusion, but suggest it is due to different bargaining institutions between the Old and New Worlds.

2. Theoretical models of the impact of unions on innovation

There are several theoretical mechanisms through which unions might have an effect on innovative activity. These mechanisms include: (i) direct effects ('Luddism'), (ii) relative price effects, (iii) profitability, (iv) 'hold up' problems and (v) strategic R&D. Over the last two decades there has been much emphasis placed on the hold up problem after the seminal article by Grout (1984), but recent theoretical interest has focused on strategic R&D issues.

2.1 Direct effects: "Luddism"

Unions have long had reputations for attempting to block the introduction of new technologies and are the institutional heirs to the Luddites[3]. This may be because of the fear of job losses, change or work intensification following new technology. For example, the British unions representing the print-workers for the national newspapers were renowned for the long-standing opposition to the introduction of computerised typesetting. This changed only when the owners of these newspapers (led by Rupert Murdoch) closed down their production shops in central London and moved completely to a new location in the east of London. Were this example generally true, unions would be a direct a break on technological diffusion.

Some companies use their inventions in their own establishments since there are some complementarities between usage and invention - an innovating firm may know more about the pros and cons of its new device than a rival[4]. If such a firm knows that there is a truculent labour force downstream that may block the introduction of new technology, this is likely to depress R&D activities upstream (or at least lead to its outsourcing).

On the other hand, there are several reasons why unions may actually be able to boost productivity – for example, by reducing grievances and staff turnover or by improving morale and training. This is the *collective voice* of unionism highlighted by Freeman and Medoff (1984). This may make the introducing of new technology more attractive in unionized settings. Indeed, survey evidence of union attitudes usually finds considerable support for the introduction of new technology[5]. It is often remarked that unions take a more pro-productivity stance in Continental European and Japan than in countries where industrial relations are co-operative than in countries that have more adversarial industrial relations (such as the USA and the UK). This may be one reason for expecting a different relationship between union power and innovation across different countries.

2.2 Relative factor price effects

There is a straightforward relative factor price effect of the union mark-up on any substitute factor of production. Consider a simple two-factor model where there is a choice between labour and new technological capital. An increase in the relative price of labour (through union wage increases) will cause substitution of high tech machines for workers, for a given level of output (i.e. along an isoquant). On the other hand, a union-driven increase in costs will mean higher average costs, causing lower overall production (a shift to a lower isoquant) and therefore less need for all factors, including labour. The impact of unions via their wage effects will depend on the balance between the substitution and the scale effects, so that even in a purely static neo-classical model, the direction of the union relative price effect is ambiguous.

2.3 Unions and profitability under imperfect financial markets

There is a consensus in the empirical literature that unions, on average, reduce profitability (e.g. Menezes-Filho, 1997). There are two routes by which this occurs. First, and most importantly, unions increase the overall compensation for their members. Secondly, unions may lower the level of productivity through featherbedding, industrial action and by creating a more antagonistic climate of industrial relations. The productivity impact of unions is more ambiguous, however, as unions may increase productivity in some settings, for example by discouraging turnover (see Freeman and Medoff, 1984, and sub-section 2.1 above). Nevertheless, even if there were a positive effect of unions on productivity it would not seem to empirically outweigh the union wage mark-up.

The lower profitability in unionised firms does not necessarily reduce investment in R&D. In principle, if unions merely redistribute excess profits from shareholders to workers then there may be no effect on R&D. Unions would act as a pure rent-sharing device and other factors would still be used at their efficient levels. Optimal investment decisions would still be made with respect to the fundamentals (see Modigliani and Miller, 1958). Unfortunately, in a world where there are imperfect capital markets firms will sometimes find themselves financially constrained in their investment decisions. This is likely to be a particular problem for R&D investments due to its inherent high risk, the fact it cannot be collateralized (as it is mainly composed of human assets) and the deep informational asymmetries between inventors and investors[6]. Companies may be very reluctant to turn to external finance to raise money for innovation, as potential investors will demand information to demonstrate the value of the R&D. This information could 'leak out' to rival firms and be used imitate the invention, undermining its value. There is ongoing controversy regarding the extent of financial constraints, but empirically many researchers have found supporting evidence that the financial constraints seem to bite more tightly for R&D than other forms of investment (see the survey in Bond and Van Reenen, 2002).

2.4 'Hold Up' problems

Grout (1984) built on Simons' (1944) model of the negative impact of unions on investment because of their appropriation of quasi-rents from investment. The mechanism is quite simple when extended to R&D as a specific form of investment. R&D has a large element of sunk cost (about 90% of R&D is current expenses on staff costs and materials). Once an R&D investment is in place and an innovation has successfully been introduced, it is possible for a union to 'hold up' the shareholders by demanding higher wages[1].

Figure 1 gives the extensive form of a simple game to show this possibility. In stage I the firm chooses R&D ('high' or 'low') and in stage II the union chooses the wage ('high' or low'). The union would like to commit to a low wage strategy conditional on the firm choosing high R&D. This way the pie is bigger (10 compared to 8) and both parties can gain (both get a pay-off of 5 as opposed to 4). However, the union cannot credibly commit to a low wage strategy in advance; because once the R&D investment is sunk there exists a strong temptation to deviate from any agreement. It is clear that the union's best response at stage II is always to play a high wage strategy. The firm knows this to be the case in stage I, and will always choose a low R&D policy. The only sub-game perfect equilibrium therefore is the {low R&D, high wage} outcome.

[Figure 1 about here]

This game has the form of a prisoners' dilemma and, as usual, there may be many ways 'out' of the dilemma by changing the structure of the game. Grout himself suggested that the first best could be achieved if unions and firms could get together and bargain over investment as well as wages. This is a common and intuitive result. It is symmetrical to the contrast between the 'right to manage' union model (where

[1] Empirical evidence tends to show a positive impact of new innovations on wages (see Van Reenen, 1996, for example, or the survey in Chennells and Van Reenen, 2002).

there is bargaining only over the wage) and the efficient bargaining model (where there is bargaining over both wages and employment). The latter is Pareto efficient and the former is not (e.g. Leontief, 1946).

Unfortunately this 'solution' to the Grout model faces a similar problem to the 'efficient bargaining over employment' model. Explicit union bargaining over employment is seldom empirically observed. Bargaining over the introduction of new technology or investment is still rarer, and bargaining over R&D itself is almost *never* seen. One response to this criticism is the argument that some kind of 'implicit' bargaining takes place over other instruments. It is difficult to see how this would practically come about. With employment, one could imagine that effort bargaining (e.g. over manning levels) gets us some way towards the efficient solution[7], but there seems little analogous mechanism for an implicit bargain over R&D[8].

A version of the implicit contract argument is that the long-term labour contracts, such as those in large Japanese companies, act as a kind of commitment device. Japanese workers can effectively commit themselves not to appropriate the rents from innovation. Unfortunately, this is certainly not the case in Britain and the United States where contracts are more short term (three years generally being the maximum). Ulph and Ulph (1989) have suggested that this may be a reason for the differential effects of unions on innovation across different countries. Even when contracts are more durable, however, commitments are likely to be difficult to sustain when there is uncertainty and significant informational asymmetries between the players.

Another related 'escape route' from the hold up problem is to notice that the game between unions and firms is repeated over time rather than being a one-shot game. Van der Ploeg (1987), for example, stressed the damage to a union's reputation in seeking to expropriate a firm's quasi-rents from innovation.

An important element of these models will be the degree to which unions discount the future. It is quite likely that the time horizons for unions are lower than the time horizons for firms, because unions do not hold property rights in jobs. High turnover or the control of the union by senior members who are looking to retirement will lower the discount factor of the union vis-à-vis the firm. This is one of the insights of Baldwin (1983). She also shows that, in the presence of union demands for sharing the returns from long-lived capital investment, investors may choose a self-enforcing counter-strategy of investing in less efficient plant and equipment or, alternatively, to try and extend the union's time horizon.

Addison and Chilton (1998) focus on the possibility of efficient investment and employment outcomes in explicitly repeated games. They firstly follow Espinosa and Rhee (1989), assuming the following structure: firstly the firm chooses capital which then remains fixed. There follows a repeated game where union chooses wages and the firm sets employment, conditionally on the wage chosen. In this framework, Espinosa and Rhee (1989) show that, so long as the discount factor is sufficiently close to one, there exist equilibria where neither the firm nor the union will be tempted to deviate, because they would find the punishment too harsh. The resulting equilibria will encompass the monopoly union and the fully efficient bargaining models as particular cases that result from certain discount rates.

Addison and Chilton (1998) also extend this model to allow the firm to choose capital at the beginning of each sub-game. Capital flexibility, besides raising the punishment the firm can impose on a deviating union (as in Baldwin, 1983), also weakens the union's punishment of the firm that cheats, introducing the possibility of opportunistic behavior on the part of the firm as well and making the efficient outcome depend crucially on the firm's discount factor.

In some cases (e.g. US ship-building) the assumption that the repeated game will go on forever[9] breaks down when unions are clearly in an 'end-game' situation of a sector in terminal decline (e.g. Lawrence and Lawrence, 1985). In this case, the firm knows that the union will pay non-cooperatively in the final sub-game and this will unravel the incentive to co-operate in previous sub-games.

Another implication of the hold-up model is that firms may take action to mitigate the degree to which they can be expropriated in other ways. Bronars and Deere (1991) suggest that firms may alter their financial structure (e.g. leveraging up the debt-equity ratio to increase the risk of bankruptcy) to reduce the incentive of unions to expropriate the innovative rents. Bronars, Deere and Tracy (1994) emphasis the incentive to license out technology rather than develop it in-house.

It has been observed that firms could also 'hold up' the sunk investments of workers in training and that this will lead to an under-investment in human capital. In this model unions could act to prevent the hold up problem by making the firm honour its commitments. This may lay behind the positive impact of unions on training that is often observed (e.g. Green, Machin and Wilkinson, 1999)).

2.5 Strategic R&D

There is a more recent body of theoretical literature that has cast doubt on the robustness of the negative impact of unions on R&D through the 'hold up' mechanism. This literature notes that R&D is mainly performed by large firms who operate in oligopolistic industries. The strategic interactions of these firms is critical to modern game theoretic models of R&D, but are wholly absent in Grout's model, which is in the context of a monopolistic firm facing a single union. The introduction of strategic interaction undermines the analytical clarity of the Grout result.

In a strategic R&D game, firms invest in R&D at the first stage of the game in the knowledge that they will be competing against each other at the second stage of the game. Investments in R&D can shift the advantages at this second stage in various ways. Much theoretical effort has been expended analyzing the role of market structure in affecting firm's R&D decisions: this was the focus of interest of much of Schumpeter's work and reappears in the modern endogenous growth literature (e.g. Aghion and Howitt, 1992). For example, consider the R&D incentives of a monopolist facing a potential entrant in an R&D game. Assume that R&D is determined by a first price sealed bid auction where the firm that bids the most (i.e. spends the most on R&D) will certainly obtain an innovation with infinitely lived patent protection[10]. In this case the current monopolist will have a greater incentive to invest in R&D than the challenger and will always invest most in R&D so long as the innovation is 'non-drastic' (i.e. both firms will be able to remain in the market post-innovation and earn positive profits). The reason for this result is that if the challenger wins the innovation and enters the market there will be a duopoly. Since joint industry profits in a duopoly will never exceed monopoly profits, the monopolist always has an additional incentive to bid harder in the R&D auction than the potential entrant. This is sometimes known as the 'efficiency effect' as monopoly is privately more efficient for the industry players than a duopoly.

A more realistic alternative to an auction model of R&D is a patent race where there is some uncertainty over who will win the race (this is still a one shot tournament model). Firms invest in R&D and draw a chance of winning the race from a known, but stochastic, probability distribution. The more R&D is performed the greater is the chance of winning, but unlike the auction model, success is not guaranteed. The efficiency effect still exists in this game (giving the high market share firm an incentive to win) but there are also counterbalancing effects. In particular the current monopolist receives a stream of rents before the innovation occurs and he will be reluctant to see these replaced. The challenger does not have any current rents and the "replacement effect" will therefore make the challenger more likely to spend more on R&D.

Ulph and Ulph (1994, 1998) have established many interesting results in the context of a patent race in R&D, a Cournot duopoly in the product market and separate firm specific unions. In particular they find two interesting results when there is 'ex post' bargaining (i.e. no bargaining over R&D at the first stage, but bargaining with unions over wages and sometimes employment at the second stage):

1. When the union bargains only over the wage ('right to manage'), there is an unambiguously negative effect of union power on R&D (a generalization of the Grout result).

2. When the union bargains over employment and the wage, an increase in union power can actually *increase* R&D.

The second result is surprising and occurs in setting when the union is not 'too powerful' and places a high weight on jobs (vis-à-vis wages) in the utility function. In such a situation, the first order effect of an increase in union power is to increase employment and therefore market share. This increase in market share enhances the incentive to do more R&D due to the threat of losing this high share (this is like the efficiency effect discussed above). Some of the empirical literature has found support for this prediction (e.g. Menezes-Filho et al., 1998b)

2.6 Summary of theory

The upshot of this brief theoretical overview is that, although there are many reasons to suspect that increases in union power may reduce the incentive to invest in innovation this is not a foregone conclusion. There are some countervailing incentives and ultimately the sign and direction of the union effect is an empirical question.

There is not a standard 'R&D equation' as there is a standard human capital earnings equation, so most empirical researchers have not investigated structural models. This is probably wise as there is no consensus in the R&D literature (or in fact, in the larger investment literature) over the appropriate empirical form for an R&D equation[11]. We now turn to these empirical issues

3. Empirical issues in the relationship between innovation and unions

In this section we mainly focus on empirical issues relating to innovation, as the econometric problems related to the union variables are covered extensively elsewhere in the literature.

3.1 The measurement of innovation

The standard measure of innovation is *R&D* (research and development expenditures). This is the early-stage of the knowledge production function. Since R&D is an input measure (like fixed investment expenditure) it cannot measure the quality of the research. 'Innovative outputs' would include patents and headcounts of innovations. These innovative outputs should give rise to higher productivity in the firm who first uses them and in subsequent firms as the innovation diffuses around the economy. There are a multitude of measures of diffusion such as the adoption of computers or of other micro-electronic technologies (such as robots, numerically controlled (NC) machines, computer assisted design (CADCAM), etc). On average, these diffusion measures should be reflected in *indirect* measures of productivity (such as TFP, total factor productivity).

R&D has the great advantage over other *direct* innovation measures in that it is a continuous variable with a monetary value attached. It is more intuitive to think of $2m of R&D as twice as important as $1m of R&D, whereas the comparison of a firm with two patents as opposed to one patent is not so obvious (see below).

R&D also has the advantage that most countries have official R&D surveys that are published on an industry wide basis at fairly regular time intervals. There is now a series that compares R&D expenditure at the industry level across a wide range of OECD countries (the OECD's ANBERD dataset) from the early 1970s onwards.

This data is starting to be used extensively by researchers[12]. Although there are cross-national differences, most nations have a version of the Frascati Manual's definition of R&D, which aids comparability across countries.

Firm or establishment level comparisons of R&D are more difficult. US accounting regulations ensure that all firms listed on the stock market that perform 'material amounts' have to declare their R&D expenditure. By contrast, even the larger publicly listed British firms have only had to report R&D since 1989[13]. In most other countries the reporting of R&D remains a voluntary item in the company accounts. Apart from the restrictions in sample size, this leads to selectivity issues as the sample of firms who are voluntarily reporting R&D are a non-random sample of the population[14]. This is one reason why most published work in this area has been on US firms.

A further problem with R&D is that most small and medium sized firms, even in high-tech industries, report zero or very low levels of R&D. This is partly because the fixed costs of R&D mean that they are genuinely not performing any R&D. But it is also likely to be because smaller firms are pursuing informal research activities that are not captured by the formal R&D measures in the company accounts or in government statistics.

Patenting and innovation count data seeks to overcome this problem, as these measures are available, in principle, for all firms in the economy. The problem with patent or innovation counts is one of 'apples and oranges' – are we comparing like with like when we add up the patent numbers? Researchers who have investigated the value of patents using renewal fees have argued that the valuation is extremely heterogeneous with many "duds" (i.e. zero value patents) and a few bonanzas. Pakes (1986), for example, uses renewal fees to estimate the distribution of the value of patents and finds a huge amount of variability. It is possible to weight the counts by other measures to reflect differential valuations – for example Bloom and Van Reenen (2002) weight by number of citations. The importance of these adjustments has not yet been fully investigated in the union and R&D literature.

Patents are judged by the relevant Patent Office, an external arbitrator of value [15]. Innovation measures have the further problem that they may be subjective – managers will always tend to systematically over-estimate how 'innovative' they are[16]. This is why more objective expert-based surveys, such as the SPRU (Science Policy Research Unit) innovations dataset are desirable (see Geroski, 1990).

A third problem with counts of patents or innovations is the econometric problem that appears when highly non-linear variables are used as dependent variables. In this case, the use of Ordinary Least Squares will lead to misleading results (for example, the distribution of the error terms will take on a number of discrete values and OLS standard errors will be incorrect). Recent developments in the analysis of count data models that allow for fixed effects and dynamic adjustment have extended our ability to look into these issues (see Blundell et al., 1999, and below).

3.2 Aggregation

In our survey we consider studies at the establishment, firm and industry level. In general, the lowest level of aggregation is generally preferred from an econometric point of view, but there are several factors to take into consideration.

First, the appropriate level will partially depend on where bargaining takes place. In the US and Japan wage bargaining is overwhelmingly at the firm or establishment level. In Germany wage bargaining focuses at the industry level, so there could be a stronger argument for industry-level studies. In the UK private sector, wage bargaining (where it exists) is mainly at the firm or establishment level, although in the 1970s industry-level bargaining was predominant. The effects of unions may go beyond their wage effects however, which establishes the case for looking at a lower level of aggregation. For example, the impact on technical diffusion may different depending on the activities of unions at different plants within the same firm.

Secondly, there is an argument for aggregation if measurement is likely to be very poor at the micro level. Grouping can smooth out some of the measurement error in the micro-series that disguises the true relationship between variables (see Grunfeld and Griliches, 1960)

Finally, the establishment level may be too disaggregated since large firms usually have R&D labs on separate sites and the R&D decisions will be generally on a company wide basis. The appropriate level is more likely to be the impact of company wide variables on company wide R&D.

3.3 Unobserved heterogeneity

Consider the basic equation for the log R&D of a firm:

$$\ln R\&D_{it} = \alpha UNION_{it} + \beta' x_{it} + u_{it} \tag{1}$$

where *i* denotes firm, *t* time period, 'R&D' is R&D expenditure (usually normalized by some measure of size, such as sales or employment), *UNION* is an indicator of union power, *x* is a vector of controls and *u* is the error term.

There are a large number of controls that need to be included in *x* to avoid omitted variable bias. Most researchers have included measures of size, market structure and capital intensity, as these variables are likely to be correlated with both union status and R&D. For example, since larger firms perform more R&D and are more likely to recognise unions, a failure to control for size would leave to a spurious positive association of unions and R&D. Unions would falsely appear to be stimulating innovation.

Matters become more complex, however, with some of the variables known to affect R&D. Technological opportunity and 'appropriability', for example, are important drivers of innovative activity (see Cohen and Levin, 1989), yet these are hard to quantify at the firm level. Industry dummies may capture some of this, but if technological opportunity or appropriability vary over time, or if a firm spans several sectors (as most large firms do) then industry dummies will not solve the problem.

Menezes-Filho et al. (1998b) for example, find that the failure to control for age and sector-level technological conditions (industry R&D intensity and patent intensity) severely biases the union coefficient downwards.

One obvious variable to consider is profitability. Consider including a measure of profitability or cash flow in equation (1). If there are cash flow constraints on R&D then this variable is likely to have a positive sign in the R&D equation. If the union impact of R&D is purely through reducing profitability (see the theory section above), then the inclusion of profitability should drive any negative union impact to zero. Otherwise, some decomposition of the union effect into 'finance' vs. 'non-finance' aspects can be attempted (see, for example, Hirsch, 1992 and Bronars, Deere and Tracy, 1994). Although suggestive, the interpretation of the cash flow variable is difficult in any investment equation, as it may just signal future profitable opportunities in the industry[17]. Consequently this method is not without its problems.

A natural approach in a panel data setting (i.e. where the same firms are observed at several points of time) is to consider controlling for fixed effects. This will generally involve a variance decomposition of the error term in equation (1) into a time invariant firm specific fixed effect (η_i) which can be correlated with the observables in an arbitrary manner, a set of time dummies (τ_t) which do not vary across firms in a given time period and a truly idiosyncratic effect which is uncorrelated with all the other variables in the model (v_{it}).

$$u_{it} = \eta_i + \tau_t + v_{it} \qquad (2)$$

The technological opportunities of a firm probably do not vary too dramatically over time so may be captured fully by the firm dummies[18] or by taking differences (first differences or longer differences) of equation (1). The problem here is that union status does not vary dramatically over time so there is likely to be considerable attenuation bias from this method (see Freeman, 1984). This will tend to bias the union effect towards zero. Comparison of first differences with longer differences and within group estimators would be helpful in this regard because long differenced estimators suffer less attenuation bias than first differenced estimators.

A related problem is the fact that R&D also does not vary much over time so, even in the absence of any measurement error for the union variable, including fixed effects unnecessarily will cause a large loss in efficiency (see Griliches and Mairesse, 1997). Practically speaking, it is a difficult job to decide whether the different results of OLS compared to fixed effects is due to true unobserved heterogeneity or rather because of the low time series variation of the key variables of interest[19].

3.4 Endogeneity of union status

In equation (1) union status may not be exogenous for a variety of reasons. For example, if highly skilled environments are conducive to R&D but not to unions then this will impart a downwards bias to the coefficient. In other words we may falsely conclude that unions had a negative effect on R&D if we do not properly control for skills. If the skill composition is stable over time, however, it will be controlled for by the fixed effect. On the other hand if both R&D and union density are pro-cyclical then the union coefficient will be biased upwards and we may mistakenly believe unions have a positive impact on R&D. If these cyclical effects are purely macro-economic, the bias can be removed by the inclusion of time dummies from equation (2).

Unfortunately, there may be other shocks that equation (2) cannot deal with. For example, improved expectations of firm specific business conditions may boost R&D and union density. If this is the case there will be a positive bias to the coefficient on unions and we are the left with the usual problems of finding a valid instrument for unionisation. Such an instrument must be correlated with union status, but uncorrelated with the shock in equation (1). Standard instrumentation strategies (e.g. first differenced GMM) of using suitably lagged endogenous variables as instruments are unlikely to be convincing because of the low time series variation in union status discussed above.

Menezes-Filho et al. (1998b) use industry union density at the time of the firm's start-up as an instrument for present union density, without significant changes in their results. Conditions at the time of firm-start up are unlikely to be correlated with the current shocks to R&D. Addison and Wagner (1994) explore data variation across countries in similar industries to (effectively) use unionisation in Germany as an instrument for industry union density in the UK This may be a reasonable strategy to use if fixed effects are controlled for and the shocks to German R&D are not correlated with the shocks to UK R&D.

3.5 Heterogeneity of the union effect

Theory strongly suggests that the impact of unions is likely to be different according to several factors, such as the scope of bargaining (wages/employment/technology, wages/employment or wage only), the bargaining priorities of unions (e.g. the weight given to wages relative to jobs in the union utility function), the bargaining power of unions and the state of product market competition. Several studies have investigated one or all of these interactions with the union status variable (see below). Other studies have empirically examined how the union effect differs across different industries without specifying the reasons for this heterogeneity.

3.6 Non-linearities in the union effect and R&D disclosure

The large number of plants and firms reporting zero R&D raises several econometric issues. If the problem is pure censoring then the appropriate strategy for equation (1) is to estimate a Tobit model. If the zeros are actually related to non-random selection, because of the choice over whether or not to disclose R&D, then a sample selection model is more appropriate (Heckman, 1979). Natural instruments in the selection equation are R&D accounting regime shifts, which have affected different firms in different ways (see Menzes-Filho et al., 1998).

There should be no presumption that the impact of unions on innovation is linear. Some of the theoretical models of strategic R&D discussed above actually have direct implications that the union impact will be non-linear (i.e. positive at low levels of union power but negative at high levels of union power).

3.7 Magnitude of the union effect on innovation

The many empirical difficulties of measuring the union effect have led most researchers to focus on the qualitative issue of whether there is an effect of unions on innovation or not. The economic (as opposed to statistical) object of interest, however, is whether the magnitude of the union effect is large or small. This is particularly difficult for the innovation or diffusion measures, as these dependent variables are usually discrete and difficult to compare across studies. R&D and Total Factor Productivity are more satisfactory in this respect as, in principle, they are quantitative measures that can be compared across studies even from different countries in different time periods.

In the survey in the next section we include the quantitative size of the union effect wherever available. It is noticeable that the size of unions on R&D is often very large in the North American studies. This is rather surprising given the other more fundamental reasons for performing R&D such as the underlying science base.

4. Survey of existing empirical work

In this section we will first look at two ‘example studies’ in the US and UK (see Table 1). The first two columns are taken from Table 4 in Hirsch (1992). His measure of unionisation uses categorical variables depending on the level of density. It is clear that the unionised firms perform substantially less R&D than non-unionised firms. Dropping profitability in column (2) increases the magnitude of the union effect, but not by a large amount, suggesting that negative association is not driven by the reduction in profits caused by union presence.

The third column is an example UK study taken from Menezes-Filho et al. (1998b). As with Hirsch there is also a large, significantly negative coefficient on union density. By contrast to the US study, however, including other covariates in column (4) reverses the sign on the union variable and renders it insignificant. The important control variables are industry technological opportunity measures (R&D and patent intensity) and firm age. They interpret this as evidence that unions are generally found in older firms and in low-tech sectors, so that the negative association of R&D with unionisation is not causal. Many of the same variables are in both studies and take similar signs: for example older firms perform less R&D and more capital intensive firms do more R&D. The differences between the studies is not caused by different specifications or covariate set: Menezes-Filho et al. (1998b) took Hirsch's data and estimated identical specifications to their own and still found significant negative union effects in the US but no significant effects in the UK. Therefore, the differential union impact on R&D is more likely to be driven by different institutions surrounding bargaining in the two countries.

To put these results in a wider context, we have surveyed all the existing published work of which we are aware concerning the effects on unions on innovation, in Tables 2 through 5. We have arranged our survey in four parts, according to which measure of innovation is used as the dependent variable. Following the 'knowledge production function' approach, we examine R&D first in Table 2. Headcount measures of innovation are in Table 3 and indicators of diffusion are in Table 4. Finally, Table 5 includes measures of productivity growth.

4.1 R&D expenditures

A survey of the papers that studied the relationship between unions and R&D can be found in Table 2. There are thirteen papers in all. The six US studies all tend to find significant negative effects of unions on R&D whether at the firm level (e.g. Hirsch, 1992) or the industry level (Allen, 1988). The union effect falls slightly after controlling for profitability, suggesting that labour unions depress R&D both through a reduction in profitability (sub-section 2.3) and also through non-profit related mechanisms (such as hold up). The only Canadian study (Betts et al., 2001) reaches a similar conclusion with, if anything, even more damaging effects of unions on R&D than the US studies. Most of the studies interpret the union effect as being due to the 'hold-up' phenomenon (sub-section 2.5 above).

The European studies generally find no statistically significant linear effects of unions on R&D, once one controls for other factors correlated with union power. The two British studies at the industry level (Ulph and Ulph, 1989, and Addison and Wagner, 1994) both find that the union impact can be positive or negative depending on the precise industry under study. Menezes-Filho et al. (1998b) present results from different samples at the firm-level and at the establishment-level, which tell a similar story (as discussed in the previous section). There is a negative raw correlation between R&D intensity and unionisation but this becomes statistically insignificant when one controls for proxies for the age of the enterprise and technological opportunity. Schnabel and Wagner (1992a and 1994) also find no statistically significant association of R&D with union density in their cross section of German industries in the early 1980s[20]. Schnabel and Wagner (1994) find that works councils have a positive association with R&D and union density has a negative impact with R&D. Their interpretation is that there is a non-linear effect of union power on R&D: "the presence of a works council is positive for R&D if union density is not too high".

Many of the studies examining the impact of unions on R&D use panel data where the same firms are observed over time. It is therefore possible, in principle, to control for fixed effects by examining the impact of *changes* in unionisation on *changes* in R&D. When this has been attempted, the union effect tends to fall into insignificance even in the US studies. This could be indicative of the fact that the negative union effect is spurious and driven by some other unobserved variables (such as managerial quality). However, both unionisation and R&D have very little time series variation and, as discussed above, this will tend to cause both attenuation bias and large standard errors, which may disguise any true causal effects of unions on R&D.

The models of strategic R&D discussed in section 2 imply that the union effect on R&D may exhibit non-linearities. Menezes-Filho et al. (1998a) explicitly test for these and do find some evidence consistent with the theory. They find an 'inverted U' relationship whereby small increases in union density can actually have a positive effect on R&D, although there is a negative and significant impact at higher levels of union power (this is also the interpretation of Schnabel and Wagner, 1994, of their results in German establishments). Furthermore, this pattern is only true of establishments where there is some bargaining over employment. When unions only bargain over wages the union impact is uniformly negative. This is consistent with some of the models of unions and strategic R&D discussed in sub-section 2.5 above.

A similar pattern is not exhibited in the North American studies. A re-analysis of the Hirsch data or the Betts et al. (2001) study reveals a pretty uniformly negative impact of unions on R&D.

4.2 Innovation

We are only aware of five econometric studies examining the impact of union power on counts of innovations (the output of R&D). Again, two US studies (Acs and Audretsch, 1988, and Hirch and Link, 1987) find significant negative effects, whereas the European studies generally find insignificant effects. Schnabel and Wagner (1992b) find no significant effects of unions in their sample of German establishments. Both the Geroski (1990) and Blundell et al (1999) studies use the UK SPRU panel that contains scientists' identification of major innovations between 1945 and 1983. Geroski uses the innovations data at the industry level whereas Blundell et al (1999) use it at the firm level. The Blundell et al. (1999) study is the most sophisticated attempt to control for fixed effects using a variety of methods[21]. Although unionisation does tend to be more robustly negative in this study than in the UK R&D studies surveyed above, the measure of unionisation is defined at the 2-3 digit industry level rather than at the firm level, so unionisation could be reflecting some other industry level factors.

4.3 Diffusion

A wide variety of countries are represented in table 4 that contains results from ten studies examining the impact of unions on the diffusion of new technologies (US, Canada, Australia, Britain and Germany). The results vary widely from the negative and significant in Australia (Drago and Wooden, 1994) to positive and often significant in the UK (e.g. Machin and Wadhwani, 1991). There are often positive raw correlations between unions and diffusion, but unionisation usually becomes insignificant when other variables such as higher wages and training are included in the covariate set (e.g. Keefe, 1991)[22].

There are two serious problems with most of these studies. First, the measures that they use are usually quite crude – a simple binary dummy for the adoption of a particular technology is most common. Unlike R&D which can be measured in a currency, there is no natural numeraire to compare the intensity of use of a technology. Secondly, the studies are generally cross-sectional which limits the amount of information available and prevents the authors from even attempting to control for fixed effects.

4.4 Productivity growth

Unions may have an impact upon either the level and/or the growth of productivity. If it is the level of unionisation that is included in the productivity growth regression, than what is being estimated is the union impact on productivity growth. If, on the other hand, a measure of changes in unionisation is included as a regressor, then its estimated coefficient will capture the impact of unions on the level of productivity, since this specification can be seen as a first-differences transformation of one relating the level of productivity to the level of unionisation (perhaps to eliminate some fixed effects).

The interpretation of the findings is also interesting in these two cases. The effect of unionisation on productivity growth could be the result of its impact on innovations or on the level of R&D expenditures, which would then be transmitted to changes in productivity growth. The impact of unionism on the level of productivity may reflect a "collective voice" effect (e.g. unions may lower turn over, Freeman and Medoff, 1984) or a "shock" effect, with managers adopting a more efficient structure of production as a reaction to unionism (see Hirsch and Link, 1984). It is important to note that the effects of unions on the "levels" and the "changes" of productivity need not go in the same direction. Finally, the interpretation of the impact of unions on productivity growth may also depend on the specific institutional framework surrounding the bargaining process, which obviously varies across countries, but may also vary for the same country over time (such as the UK in the 1980s).

The results of the studies that examined the relationship between unionism and productivity growth are contained in Table 4. These studies are concentrated in the US and in the UK, although some evidence is becoming available for less developed countries. The first US studies (Mansfield, 1980 and Link, 1981) found a negative effect union density effect on the average annual rate of change in total factor productivity. Maki (1983), using time series data from Canada, found a positive union effect on the level of productivity and a negative one on productivity growth. Allen (1988), using industry level data, found the same, but both effects were found to be statistically insignificant. Hirsh and Link (1984) found both effects negative (and statistically significant). Hirsch (1991), in one of the most complete US studies to date, used firm level panel data to find a negative effect of unionism on productivity growth, but this effect was found to be weak when industry effects were controlled for and insignificant when corrected for firm specific serial correlation in the error term. Therefore, it seems that there is a relative consensus in the US literature of a negative union impact on productivity growth, but this is also subject to the criticism that unionism may in fact be picking up other unobserved effects.

It is also important to note that, for most of the studies, R&D is included on the right hand side of the productivity regressions as an extra covariate. It would be interesting to examine the results excluding R&D from the equation, as that would allow the researcher to uncover the indirect impact of unions on productivity via R&D.

In the UK, the interpretation of the results is clouded by the weakening of the trade unions in the 1980s, due to the legal and political changes under Mrs. Thatcher's government. For example, Nickell et al. (1992) and Gregg et al. (1993) find significant *positive* effects of the level of unionism on the growth of productivity at the beginning and in the end of the 1980s, respectively. They interpret this as reflecting the fact that during the 1980s managers in unionised firms were able to assert their 'right to manage' and introduce organizational changes that had been resisted by the unions when they were stronger in the 1970s. Additional evidence is presented by the Nickell et al. (1992) study that finds a *negative* effect of the level of union density on productivity growth in the late 1970s when it is argued that unions were becoming stronger due to a favourable legislative environment. Gregg et al. (1993) also found that the rise in productivity in the late 1980s was stronger among the unionised firms that de-recognised unions in some of their plants, suggesting also a negative effect of unionism on the *level* of productivity. So the interpretation of the UK studies is that unions have a negative effect on the level of productivity, but not on the growth of productivity (which is consistent of the absence of a significant negative union effect on R&D in the UK).

Outside the US and UK, the literature is far scantier. In what seems to be the first study in Latin America, Menezes-Filho et al. (2002) find that there is a negative but insignificant correlation between unionism and productivity growth in Brazil in the 1990s. However, when the authors allow for a non-linear relationship they find that at low union density levels, an increase in union density tends to increase the rate of productivity growth, but at a decreasing rate, just as Menezes-Filho et al. (1998b) found with UK R&D intensity.

5. Conclusions

There is a general view that unions tend to retard innovation for a wide variety of reasons. In this paper we have examined the different theories that could lead to union power changing the incentive and abilities of firms to innovate. Although there are many ways in which unions could indeed slow down technological advance, there are also circumstances in which unions could foster new technology, so that a blanket condemnation in the absence of rigorous empirical evidence is unwarranted.

We have examined almost forty separate empirical studies of the impact of unions on innovation as measured by four different indicators: R&D, innovation headcounts, technology diffusion and productivity growth. In our view, there is a reasonable consensus in the empirical literature of the impact of unions on some economic measures. Unions have a clear positive effect on wages and a clear negative effect on profitability. There are no grounds for such a consensus on the impacts of unions on innovation. The sign, size and statistical significance of the association of unions with innovation vary dramatically from study to study. However, there do appear to be some patterns that have emerged.

First, the North American (overwhelmingly US) studies find consistently negative impacts of unions on R&D. At face value this is extremely damaging to the US union movement. R&D is the basis of growth and if unions damage R&D they are undermining their own long-term survival chances, as well as damaging the few remaining industries where they remain strong.

Second, the European studies do not find that unions generally reduce R&D. Interestingly, this statement is true not just in the Continental European countries with "co-operative" industrial relations (like Germany) but also in the UK where relations are usually described as "adversarial". The raw negative correlation can be accounted for by the fact that unions are found in older, low-tech industries. This difference between the UK and US studies does not appear to be driven by differences in specification. It is more likely to reflect differences in institutions. One hypothesis would be that UK unions place a higher weight on jobs than wages in their utility functions than their US counterparts. The fact that the union wage mark-up is about twice as large in the US as in the UK is consistent with this hypothesis. Placing a greater emphasis on jobs than wages should mitigate the size of the union tax on R&D and may even help some firms boost their R&D spend in some models. It may also be a reason why European unionisation (even in the UK) is more resilient than in the US

A third finding is that there does appear to be a mildly negative association of union power with productivity growth, especially at higher levels of union density. This is less strong than the US R&D evidence, but does seem to emerge from most of the studies (although it is often difficult to interpret, as in the UK studies of the 1980s). This should be a serious cause for concern. Many firms do not depend upon formal R&D for their survival (at least not their own R&D), but all firms will rely on their own productivity growth if they are to prosper in the longer run. Productivity growth in firms depends not only on technology, but also on 'innovation' more widely, including innovation in new organizational forms (decentralization, delayering, performance pay, just-in-time production, team-working, etc). Unions are often suspicious of these organizational changes and resist them more than new technologies (Daniel, 1987).

Finally, we should end with some methodological points. The knowledge base we draw on is much thinner in this area than in other areas of union research. There have been fewer systematic attempts to deal with the well-known problems of endogeneity and fixed effects. Is the negative union effect on R&D in the North America studies really causal or does it reflect some further unmeasured influence on both unions and R&D? Is there really a non-linear union effect or is it just another reflection of measurement error in the union density variable? There is also a need to expand the samples of countries under study that are still very Anglo-Saxon biased. With the growth of cross-European datasets on innovation and micro-data sets in developing countries, data availability is no longer an excuse. The important issue of the effect of labour market institutions on innovation and growth needs to spread its empirical net wider and deeper.

References

Acs, Zoltan and Audretsch, David (1988). 'Innovation in Large and Small Firms: An Empirical Analysis', American Economic Review, 78 (4), 678-90.

Aghion, Philippe and Howitt, Peter (1992) 'A Model of growth through creative destruction' Econometrica 60 (2) 323-351

Addison, John T. and Hirsch, Barry T. (1989) 'Unions Effects on Productivity, Profits and Growth: Has the Long Run Arrived?' Journal of Labour Economics, 7 (1), 72-105.

Addison, John T. and Chilton, J. (1998) 'Self-Enforcing Union Contracts: Efficient Investment and Employment', Journal of Business, 71 (3), 349-69.

Addison, John T. and Wagner, Joachim (1994) 'UK Unionism and Innovative Activity: Some Cautionary Remarks on the Basis of a Simple Cross-Country Test', British Journal of Industrial Relations, 32 (1) , 85-98.

Allen, Steve (1988) 'Productivity Levels and Productivity Change under Unionism' Industrial Relations, 27 (1), 94-113

Arrow, Kenneth (1962) 'Economic Welfare and the Allocation of Resources for Invention' 609-625 in The Rate and Direction of Inventive Activity, edited by Richard Nelson, Princeton: Princeton University Press

Baldwin, C. (1983) 'Productivity and Labour Unions: an Application of the Theory of Self-Selection Contracts', Journal of Business, 56 (2), 155-85.

Beath, John, Katsoulacos, Yannis and Ulph, David (1995) 'Game-Theoretical Models of Innovation' 150-187 in Paul Stoneman (ed), Handbook of Innovation, Oxford: Basil Blackwell.

Benvignati, A. (1982) 'Inter-firm adoption of capital goods innovations' Review of Economics and Statistics, 64(2), 33-335

Berman, Eli, Bound, John and Griliches, Zvi (1994) 'Changes in the Demand for Skilled Labor within US Manufacturing Industries: Evidence from the Annual Survey of Manufacturing', Quarterly Journal of Economics, 109(2), 367-98.

Betcherman, George (1988) 'Technological Change and its impacts: Do unions make a difference?' Proceedings of the 1987 Annual Meetings of the Canadian Industrial relations Society 65-78

Betts, Julian R., Odgers, Cameron W. and Wilson, Michael K. (2001) 'The Effects of Unions on R&D: An Empirical Analysis using Multi-Year Data', Canadian Journal of Economics, 34 (3), 785-806.

Bloom, Nicholas and Van Reenen, John (2002) 'Patents, Real Options and Firm Performance', Economic Journal, 112 (March), C97-C116.

Blundell, Richard, Griffith, Rachel. and Van Reenen, John (1999) 'Market Structure and Innovation: Evidence from British Manufacturing Firms', Review of Economic Studies 66(3), 529-554.

Bond, Steven, Harhoff, Dietmar and Van Reenen, John (1999) 'Investment, R&D and Financial Constraints in Britain and Germany' Institute for Fiscal Studies Working Paper No. 99/5

Bond, Steven and Van Reenen, John (2002) 'Micro-econometric Models of Investment and Employment', forthcoming in Heckman, James and Leamer, Edward. (eds), Handbook of Econometrics, *v*ol. 6. Amsterdam: North Holland

Borghans, Lex and ter Weel, Bas (2002) 'Computers, Skills and Wages', mimeo Maastricht University

Bound, John, Cummins, George, Griliches, Zvi, Hall, Bronwyn and Jaffe, Adam (1984) 'Who does R&D and Who Patents?', in Zvi Griliches (ed) R&D, Patents and Productivity. Chicago: Chicago University Press 130-167.

Bronars, Steven and Deere, Donald (1991) 'The Threat of Unionisation, the Use of Debt and the Preservation of Shareholder Equity', Quarterly Journal of Economics, 106 (1), 231-253.

Bronars, Steven and Deere, Donald (1993) 'Unionisation, Incomplete Contracts and Capital Investment', Journal of Business, 66(1),117-132.

Bronars, Steven, Deere, Donald and Tracey, John (1994) 'The Effects of Unions on Firm Behaviour: An Empirical Analysis using Firm Level Data' Industrial Relations, 33(4), 426-451.

Carlin, Wendy, Glyn, Andrew, and Van Reenen, John (2001) 'Export Market Performance of OECD Countries: an Empirical Examination of the Role of Cost Competitiveness in an OECD Panel of Industries' Economic Journal, 110(468), 1-35.

Chennells, Lucy and Van Reenen, John (1997) 'Technical Change and Earnings in British Establishments', Economica, 64 (256), 587-604.

Chennells, Lucy and Van Reenen, John (2002) "The effects of technical change on skills, wages and employment: A Survey of the Micro-econometric evidence" Chapter 5, 175-224 in L'Horty, Y. and Greenan, N., and Mairesse, J. Productivity, Inequality and the Digital Economy, Cambridge: MIT Press

Cohen, Wesley and Levin, Richard (1989) 'Empirical Studies of Innovation and Market Structure' in Schmalensee, Richard and Frank Willig (eds) The Handbook of Industrial Organization, vol. 1, Amsterdam: North-Holland. 1059-1107

Connolly, Richard, Hirsch, Barry and Hirschey, Mark (1986) 'Union Rent Seeking, Intangible Capital and the Market Value of the Firm', Review of Economics and Statistics, 68 (4), 567-77.

Daniel, WilliamW. (1987) Workplace Industrial Relations and Technical Change Dorset: Blackmore Press

Drago, Richard and Wooden, Mark (1994) ‘Unions, investment and innovation: Australian evidence’ Applied Economics, 26 (6), 609-615

Espinosa, Maria P. and Rhee, Changyong (1989) ‘Efficient Wage Bargaining as a Repeated Game’, Quarterly Journal of Economics, 104(3), 565-88.

Fitzroy,Felix and Kraft, Kornelius (1990) `Innovation, Rent-Sharing and the Organization of Labour in the Federal Republic of Germany’ Small Business Economics, 2(4) 95-103

Freeman, Richard and Medoff, James (1984) What do Unions Do? New York: Basic Books.

Freeman, Richard (1992) ‘Is Declining Unionism of the US Good, Bad or Irrelevant?’ in Mishel, L. and Voos, P. (eds) Unions and Economic Competitiveness. Economic Policy Institute. 143-169

Freeman, Richard (1984). ‘Longitudinal Analysis of the Effect of Trade Unions’, Journal of Labor Economics, 2 (1), 1-26.

Geroski, Paul (1990) ‘Innovation, Technological Opportunities and Market Structure’, Oxford Economic Papers, 42(3), 586-702.

Geroski, Paul (1995) Market Structure, Corporate Performance and Innovative Activity, Oxford: Oxford University Press.

Gilbert, Richard and Newberry, David (1982) ‘Preemptive Patenting and the Persistence of Monopoly’ American Economic Review, 72(3), 514-526

Green, Francis, Machin, Stephen and Wilkinson, David (1998). 'Trade Unions and Training Practices in British Workplaces', Industrial and Labor Relations Review, 52(4), 179-95.

Gregg, Paul, Machin, Steve and Metcalf, David (1993). 'Signal and Cycles? Productivity Growth and Changes in Unions Status in British Companies: 1984-1989', Economic Journal, 103(419), 894-907.

Griffith, Rachel, Redding, Steve and Van Reenen, John (2000) 'Mapping the Two Faces of R&D: Productivity Growth in a panel of OECD industries' CEPR Discussion Paper No. 2457

Griliches, Zvi and Mairesse, Jacques (1997) 'Production Functions: The Search for Identification', in Stephen Strom (ed), Essays in Honour of Raynar Frisch. Cambridge: Econometric Monograph Series 231-266.

Griliches, Zvi (1998) R&D and productivity: The Econometric Evidence, Chicago: Chicago University Press

Grout, Paul A. (1984) 'Investment and Wages in the Absence of Binding Contracts: a Nash Bargaining Approach', Econometrica, 52 (2), 449-60.

Grunfeld, David and Griliches, Zvi (1960) 'Is aggregation necessarily bad?' The Review of Economics and Statistics XLII (1) 1-13

Heckman, James (1979) 'Sample Selection Bias as a Specification Error', Econometrica, 47(1), 153-161.

Himmelberg, Charles and Petersen, Bruce (1994) 'R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries', Review of Economics and Statistics, 76(1) 38-51

Hirsch, Barry T. (1991) Labour Unions and the Economic Performance of US Firms. Kalamazoo: Upjohn Institute

Hirsch, Barry T. (1992) ‘Firm Investment Behaviour and Collective Bargaining Strategy’, Industrial Relations, 31(Winter), 95-121

Hirsch, Barry T. and Link, Albert N. (1987) ‘Labor Union Effects on Innovative Activity’, Journal of Labor Research, 8(Fall , 323-32.

Hirsch, Barry T. and Link, Albert N. (1984) ‘Unions, Productivity and Productivity Growth’, Journal of Labor Research, 5(Winter), 29-37.

Johnson, George E. (1990) ‘Work Rules, Featherbedding and Pareto-optimal Union-Management Bargaining’ Journal of Labor Economics, 8(2) S237-259.

Keefe, James H. (1991) ‘Do Unions Influence Technological Progress?’, in Industrial and Labor Relations Review, 44(2) 261-274

Kelley, Mark and Brookes, Harold (1991) The State of Computerised Automation in US Manufacturing. Cambridge: MIT Press

Latreille, Paul (1992) “Unions and the inter-establishment adoption of new technologies in the British private manufacturing sector” Oxford Bulletin of Economics and Statistics, 54 (1), 31-49

Lawrence, Charles and Lawrence, Robert (1985) ‘Manufacturing Wage Dispersion: An End Game Interpretation’ Brookings Papers on Economic Activity, 1:4-116

Layard, Richard and Nickell, Steve (1999)’Labor Market Institutions and Economic Performance’ in Orley Ashenfelter and David Card (eds), Handbook of Labor Economics, vol. 3C, Amsterdam: Elsevier. 267-312

Leontief, Wassily (1946) ‘The Pure Theory of the Guaranteed Annual Wage Contract’ Journal of Political Economy 54 (2), 76-79

Link, Albert (1981) 'Basic Research and Productivity Increase in Manufacturing: Additional Evidence', American Economic Review 71(5) (1111-1112.

Link, Albert (1982) `Productivity growth, environmental regulations and the composition of R&D', Bell Journal of Economics, Autumn, 548-554

Lintner, Victor, Pokorny, Mikheal J., Woods, Michael M., and Blinkhorn, Michael R. (1987) `Trade Unions and technical change in the UK Mechanical Engineering Industry' British Journal of Industrial Relations, 25(1), 19-29

Machin, Steve and Van Reenen, John (1998) 'Technology and Changes in the Skill Structure: Evidence from Seven OECD Countries', Quarterly Journal of Economics, 113 (4), 1215-44.

Machin, S. and Wadhwani, S. (1991) 'The Effects of Unions on Organizational Change, Investment and Employment', Economic Journal, 101(407), 324-330.

Maki, David (1983) 'The Effect of Unions and Strikes on the Rate of Growth of Total Factor Productivity in Canada', Applied Economics*, 15(February), 29-41.*

Mansfield, Edward (1980) 'Basic Research and Productivity Increase in Manufacturing', American Economic Review 70(5), 863-73.

McDonald, Ian and Solow, Robert (1981) 'Wage Bargaining and Employment' American Economic Review 71(3), 896-908

Menezes-Filho, Naercio A. (1997) 'Unions and Profitability over the 1980s: Some Evidence on Union-Firm Bargaining in the UK', Economic Journal, 107(442), 651-670.

Menezes-Filho, Naercio A., Ulph, David and Van Reenen, John (1998a) 'The Impact of Unions on R&D: Empirical Evidence' European Economic Review, 42(3-5), 919-930

Menezes-Filho, Naercio A., Ulph, David and Van Reenen, John (1998b) 'R&D and Union Bargaining: Evidence from British Companies and Establishments' Industrial and Labor Relations Review, 52(1), 45-63.

Menezes-Filho, Naercio. A., Zylbertajn, H., Chahad, J. and Pazello, E. (2002) 'Trade Unions and the Economic Performance of Brazilian Establishments', University of Sao Paulo, mimeo.

Millward, Neil, Stevens Mark, Smart, Steven and Hawes, William R. (1992) Workplace Industrial Relations in Transition. Hants:Dartmouth.

Modigliani, Frank and Miller, Marcus (1958) 'The cost of capital, corporation finance and the theory of investment' American Economic Review, 48(3), 261-197

Nickell, Steve, Wadhwani, Sushil and Wall, Martin (1992) 'Productivity Growth in UK Companies', European Economic Review, 36(3-5), 518-36.

Pakes, Ariel (1986) 'Patents Options: Some Estimates of the value of holding European Patent Stocks' Econometrica 54(4), 755-784

Schnabel, Claus and Wagner, Joachim (1992a) 'Unions and Innovative Activity in Germany', Journal of Labour Research, 13(8), 393-406.

Schnabel, C. and Wagner, J. (1992b) 'Unions and Innovations: Evidence from Germany', Economics Letters, 39, 369--73.

Schnabel, Claus and Wagner, Joachim (1994) `Industrial Relations and Trade Union effects on Innovation in Germany' Labour 8(3) 489-503

Simons, Herbert (1944) 'Some Reflections on Syndicalism', Journal of Political Economy, 52(1), 1-25.

Stewart, Mark (1995) 'Union Wage Differentials in an Era of Declining Unionisation' Oxford Bulletin of Economics and Statistics , 57(2), 143-166.

Taymaz, Eli (1991) `The Impact of Trade Unions on the diffusion of technology: The case of NC machine tools' British Journal of Industrial Relations, 29(2) 305-312

Ulph, Alisatir and Ulph, David (1989) ‘Labour Markets and Innovation’, Journal of Japanese and International Economics, 3 (3), 403-423.

Ulph, Alistair and Ulph, David (1994) ‘Labour Markets and Innovation: Ex Post Bargaining’, European Economic Review, 38(3-5), 195-210.

Ulph, Alistair and Ulph, David (2001) ‘Strategic Innovation with Complete and Incomplete Labor Market Contracts’, Scandinavian Journal of Economics, 103 (2) 65-282.

Van der Ploeg , Rik (1987) ‘Trade Unions, Investment and Employment’, European Economic Review 31(6), 1465-1492

Van Reenen, John (1996) “The Creation and Capture of Economic Rents: Wages and Innovation in a Panel of UK Companies” Quarterly Journal of Economics (February 1996) CXI, 443, 195-226

Table 1: The Determinants of investment in R&D: Two example studies from the US and the UK

	(1)	(2)	(3)	(4)
	US firms Hirsch (1992)		UK firms Menezes-Filho et al., 1998	
	Dependent variable is ln(R&D expenditure)		**Dependent variable is ln(R&D/Sales)**	
Union density <30%	-.281 (9.10)	-.292 (9.42)	-	-
Union density between 30% and 60%	-.315 (9.78)	-.34 (10.56)	-	-
Union density above 60%	-.438 (12.25)	-.462 (12.91)	-	-
Union density	-	-	-.470 (2.37)	0.139 (.586)
Profits	1.692 (7.37)	-	-	-
Lagged ln(R&D stock)	0.545 (49.56)	.55 (49.8)	-	-
Ln(capital)	.171 (7.13)	.153 (6.4)	-	0.442 (4.02)
Ln(labour)	.361 (14.52)	.377 (15.11)	-	Quadratic in employment
Age/100	-.163 (4.47)	-.189 (5.19)	-	-
Firm born after 1979	-	-	-	.999 (5.07)
Industry earnings	0.706 (6.73)	0.733 (6.95)	-	1.627 (2.29)
Industry R&D/Sales	-	-	-	0.381 (5.15)
Other variables	Firm growth, industry growth, industry concentration, industry imports and industry unionisation		None	Market share, industry patents per employee, firm skills
Industry and time dummies	yes	yes	yes	yes
Sample selection correction	no	no	yes	yes
N	4176	4176	339	339

Coefficients estimated by OLS and t-statistics underneath in parentheses;
Notes: *the base for columns (1) and (2) is union density = zero.*

Table 2: Unions and R&D

Authors	Methodology	Data	Indicators of technical changes & unionisation	Controls	Results
Addison and Wagner (1994)	Least Median Squares regression of British R&D/value added against union density in Britain, use German information on density to control for endogeneity	38 British industries 1989; 18 matched UK – German industries	Percentage of workers in a union from the Labour Force Survey. R&D/value added	German R&D/value added	Positive association between unions and R&D in 'low tech' industries; argued that this is due to endogeneity of unionisation. When German R&D entered in a UK R&D equation no significant effect of unions
Allen (1988)	OLS regressions of industry R&D/output by industry of origin and industry of use	74 US industries 1973-1975	1973-1975 average union density. R&D/output	1972 concentration ratio	Negative and significant R&D intensity 17% lower in unionised industries
Betts, Odgers and Wilson (2001)	Least Squares dummy variables, R&D/value added	13 Canadian industries in production sector 1968-1986	Union density. R&D/value added ('industry GDP')	Import share, Herfindahl Index of industrial concentration, growth of sales, profits	Unions have a significant and negative effect on R&D even after controlling for fixed effects; size is larger than in USA; union density rising from 25th to 75th percentile associated with a fall in R&D of 40%
Bronars and Deere (1993)	Log (R&D/capital) regressions	600 US firms (firm specific averages over sample period)	Percentage of industry who are members of trade union weighted by firm's sales across these three digit industries. R&D/fixed capital	Sales, industry dummies, sales growth, concentration, median firm size in industry	One standard deviation in unionisation rate associated with a 51.1% fall in R&D/K
Bronars, Deere and	R&D/Sales ratio averaged	120-130 US firms	Various – e.g. Bureau	Sales growth,	Unionisation has generally a

Tracey (1994)	over time: averages are taken within two distinct sub-periods: 1975-1978 and 1979-1982	1979-1982; 130-150 firms 1975-1978	of Labor Statistics contract data matched to Compustat firms, Hirsch's survey, CPS industry averages. R&D/sales	concentration, industry dummies, capital-labour ratios, investment/sales ratios	negative effect, although this is only strong in manufacturing (10% increase in unionisation associated with a 3.5-5% fall in R&D); effect not significant when industry effects included or estimates in first differences
Connolly, Hirsch and Hirschey (1986)	R&D/Sales regressions and market value including R&D as explanatory variable. Is rate of return to intangible capital lower in union firms?	367 firms from US Fortune 500 in 1977	Industry level union density. R&D/Sales	Concentration market share, advertising/sales, growth, diversification	Unions have consistently negative effects on R&D/Sales; they reduce the rate of return to R&D as measured on the stock market. Increasing unionisation from 0 to mean reduces R&D by 32%
Hirsch (1991)	Regressions of R&D on union coverage	452 US firms; 4327 observations between 1968-1980	The proportion of a firm's North American work-force covered by a collective bargaining agreement in 1972 and 1978 (retrospective questioning in 1987). Firm specific R&D lagged stock of R&D as a control; R&D/sales.	Labour, capital, firm growth, industry wages, concentration, imports, profits	Consistently negative in all specifications, especially in drugs and medicines Fixed effects of 2SLS models severely reduce union effect
Hirsch (1992)	R&D regressions of R&D on union coverage	706 US firms; 5841 observations 1972-1980	As in Hirsch (1991)	As in Hirsch (1991) plus age of firm	Always a negative effect of unions on R&D
Menezes-Filho, Ulph and Van Reenen	Log(R&D/sales) regression with correction for	Panel of 446 UK firms 1983-90	R&D as reported in company accounts	Age, size, skills, market share,	Raw correlation between unions and R&D

(1998b)	selectivity of R&D disclosure		Union recognition and union density.	capital intensity, Industry R&D, industry patents/worker, industry wage, non-random R&D disclosure	significantly negative, but insignificant when including all controls; some evidence of non-linearity (positive at low density levels, negative at high density levels).
Menezes-Filho, Ulph and Van Reenen (1998b) – cont.	Tobit regression of R&D/ expenditure and R&D employees/total employment	Cross section of up to 826 British establishments in 1990	Union recognition, union density. R&D as reported by survey of plants	Age, size, skills, industry R&D/sales, industry wage, industry patents/worker, single site	Raw correlation between unions and R&D significantly negative, but insignificant when including all controls; some evidence of non-linearity; negative impact for plants where there was no wage bargaining.
Schnabel and Wagner (1992a)	Robust regression techniques as well as OLS regressions	29 German industries 1983-1984	Union density not observed but predicted based on characteristics from individual level membership equation. R&D/Sales and % of R&D workers in total employment	Wages, concentration, firm size, capital intensity, rate of profit, capital vintage, sales growth	No significant association
Schnabel and Wagner (1994)	Least Median Squares	26 German industries in 1984/85	Union density not observed but predicted based on characteristics from individual level membership equation. R&D/Sales	Quadratic in firm size, average wage, profitability, concentration	No significant association
Schnabel and Wagner (1994)	Tobit	31 German establishments in two states 1989	Union density and Works Council. R&D/sales	Quadratic in firm size, average wage,	Union power has non-linear effect: works councils (highly correlated with union

				profitability, concentration	density) had a positive and significant effect, but union density negative and significant.
Ulph and Ulph (1989)	OLS regression	33 British industries in 1972 and 1978	Percentage of workforce covered by a union agreement; percentage of workforce covered by a local agreement. R&D/sales	Concentration, high tech sector dummy	Union measures have a positive effect in low tech industries, but a negative effect in high tech industries

Table 3: Unions and direct measures of Innovation

Authors	Methodology	Data	Indicators of technical changes & unionisation	Controls	Results
Acs and Audretsch (1988)	OLS regression of count of total number of innovations normalized on employment	US Small Business Administration Dataset; 247 4-digit industries in 1982	Union density. Innovations collected from trade journals.	Capital, advertising, concentration, industry growth and skills	Negative and significant union effect
Blundell, Griffith and Van Reenen (1999)	Dynamic count data model of innovation counts, allows for fixed effects through either 'pre-entry stock' method or nonlinear General Method of Moments	UK Firm level panel data 1972-1982; Science Policy Research Unit (SPRU) innovations (1945-1982) data and Datastream company accounts	Two-digit industry union density. Science Policy Research Unit's (SPRU) innovation dataset (survey of scientists, engineers and other experts covering 1945-1983).	Lagged innovations, market share, capital, concentration, imports, time dummies, fixed effects	Unions have negative effect on innovation, significance varies in different specifications
Geroski (1990)	Region of innovations counts using OLS and within groups (i.e. inclusion of firm dummies for fixed effects)	73 British manufacturing industries; two pooled cross section 1970-1974 and 1975-1979	Percentage of workers coverage by a collective bargain (NES). Average number of innovations from Science Policy Research Unit (SPRU) innovations.	Industry Concentration, Share of Firms that entry and exit the industry, growth, imports, exports, Size	Negative but insignificant
Hirsch and Link (1987)	Ordered probits of response to question on product innovation	315 New York manufacturing firms in 1985	Binary variable if firm density over 50%.	Size, concentration, profitability,	Unions have significant and negative effect

			Question relating to company's comparative advantage in product innovation.	foreign competition, labour-management relations, R&D	
Schnabel and Wagner (1992b)	Probits of product innovation	78 German establishments in 1990	Presence of Works Councils, extent of wage drift. Product innovation.	Number of employees	Positive but insignificant effect

Table 4: Unions and technological diffusion

Authors	Methodology	Data	Indicators of technical changes and unionisation	Controls	Results
Benvignati (1982)	Probits of adoption, probits of being `pioneer' mill (if mill had adopted any advanced machinery of above average speed)	241 US textile mills	Union=1 if 10% or more of production workers are members of a union. Important textile machinery (any one of 33 different types)	Size, concentration, 4 digit industry	Unionised mills significantly more likely to be pioneers; positive but insignificant effect on adoption
Betcherman (1988)	OLS regressions on three measures of technology	536 Canadian firms 1980-85 (Working with Technology Survey)	Union present or not? Expenditure on computers (and as a % of sales) 1980-85; % of employees using technology in 1985.	Size, industry, region, ownership type	Negative but insignificant effect
Borgham and ter Weel (2002)	Logit analysis where the dependent variable is whether an individual uses a computer or not	c. 2,500 individuals in the Skill Survey of Employed British workers, 1997	Whether an individual covered by a collective bargaining agreement; membership of union. Computer use	Education, age, gender, marital status	Positive and significant effect of union coverage (interpreted as union wage effect) and negative interaction of coverage with membership
Chennells and Van Reenen (1997)	Wage and technology equation across 3 different skill groups; allow unions to affect both wages and	Pooled cross section of c.992 British establishments in 1984 and 1990 (WIRS)	Dummy for union recognition at the workplace. Has workplace been	Size, industry, single site, UK owned, employers association, skills,	Unions have no significant effect on technology once one controls for wages and other factors

	technology adoption		affected by introduction `of major new plant, equipment (involving microelectronics)` over the previous three years? Computer presence and age of plant.	gender, payment by results, local unemployment	
Drago and Wooden (1994)	Probits of technological adoption	802 Australian establishments (AWIRS) in 1990	UNION – any union members in workplace; DELEGACT – whether union delegates active in expressing concerns to management; Union density. Has workplace been affected by introduction `of major new plant, equipment or office technology` over the previous two years;	Wages, Size, capacity utilization, financial performance, demand, foreign ownership, organizational change, joint consultative committee,	Unions have a generally negative (And significant) effect. This is mitigated by (a) 'active' unions (DELEGACT) (b) very high levels of union density
Fitzroy and Kraft (1990)	Weighted least squares and tobit treating unionisation as endogenous	57 small and medium sized German firms in 1979	Proportion of sales accounted for by products introduced within the last 5 years. Union density interacted with presence of a Works Council	Industrial concentration, batch production dummy, capital, total employment, occupational proportions, exports, capital held by managers,	Union power has negative and significant effect (but work council and union density are only included as an interaction). Results when union power treated as exogenous are not presented.

				urban area dummy, incentive pay, profits.	
Kelley and Brookes (1988)	Probit of whether the establishment uses programmable automation	757 US metalworking establishments in 1987	Union recognition. Computerised automation.	Wages, organizational complexity (factor combining size and multi-plant), machining employment share, other computer use, small batch output and other organizational features	Negative but insignificant (but wages included), union highly correlated with multi-plant firms
Keefe (1991)	Seven different probits for seven types of advanced manufacturing technology	260 US plants in seven industries	Union=1 if majority of workers in the establishment are covered by a collective bargaining agreement. Seven technologies including numerically controlled machine tools (NC), machine center (MC), Computerised Numerical Control (CNC), Direct Numerical Control (DNC), CADCAM, ROBOT, FMS	Wages, training, shiftwork, plant size (number of employees),	Unions have significant negative effect on CADCAM and CNC; when training and wages dropped CADCAM variable is not significant; unions have a significant positive effect on ROBOTS variable

Latreille (1992)	Probit	418 British establishments 1984	Manual union recognition; presence of micro-electronics in production process	Size, foreign ownership, few competitors, profit-sharing, industry imports, industry sales (level and growth),	Positive and significant effect of unions
Lintner, Pokorny, Woods and Blinkhorn (1987)	OLS regressions	133 UK mechanical engineering plants 1983-84	Union recognition and density by blue collar/white collar (binary dummy). Adoption of CADCAM (Computer Aided Design and Manufacturing Equipment), CNC and flexible manufacturing systems	Number of employees in establishment, flexibility of investment, region	No significant effect of unions
Taymaz (1991)	OLS regressions	US engineering industries 1979-83 (42 observations)	Collective bargaining coverage for all workers and production workers only. Share of numerically controlled machine tools as percentage of all machine tools	Total employment, proportion of technicians, average firm size, capital/labour ratio, variance of industry growth rate, work in progress	Unions have no significant effect
Machin and Wadhwani (1991)	Probits of incidence of advanced technical change	British establishments in 1984 (WIRS)	Union recognised at workplace dummy and union density	Wages, Size, capacity utilization,	Unions have a positive association with the adoption of new technology but this

			Has workplace been affected by introduction 'of major new plant, equipment (involving microelectronics)' over the previous three years	financial performance, demand, foreign ownership, organizational change, joint consultative committee,	association is not significant after controlling for wages, organizational change, and the presence of joint consultative committees ('voice')

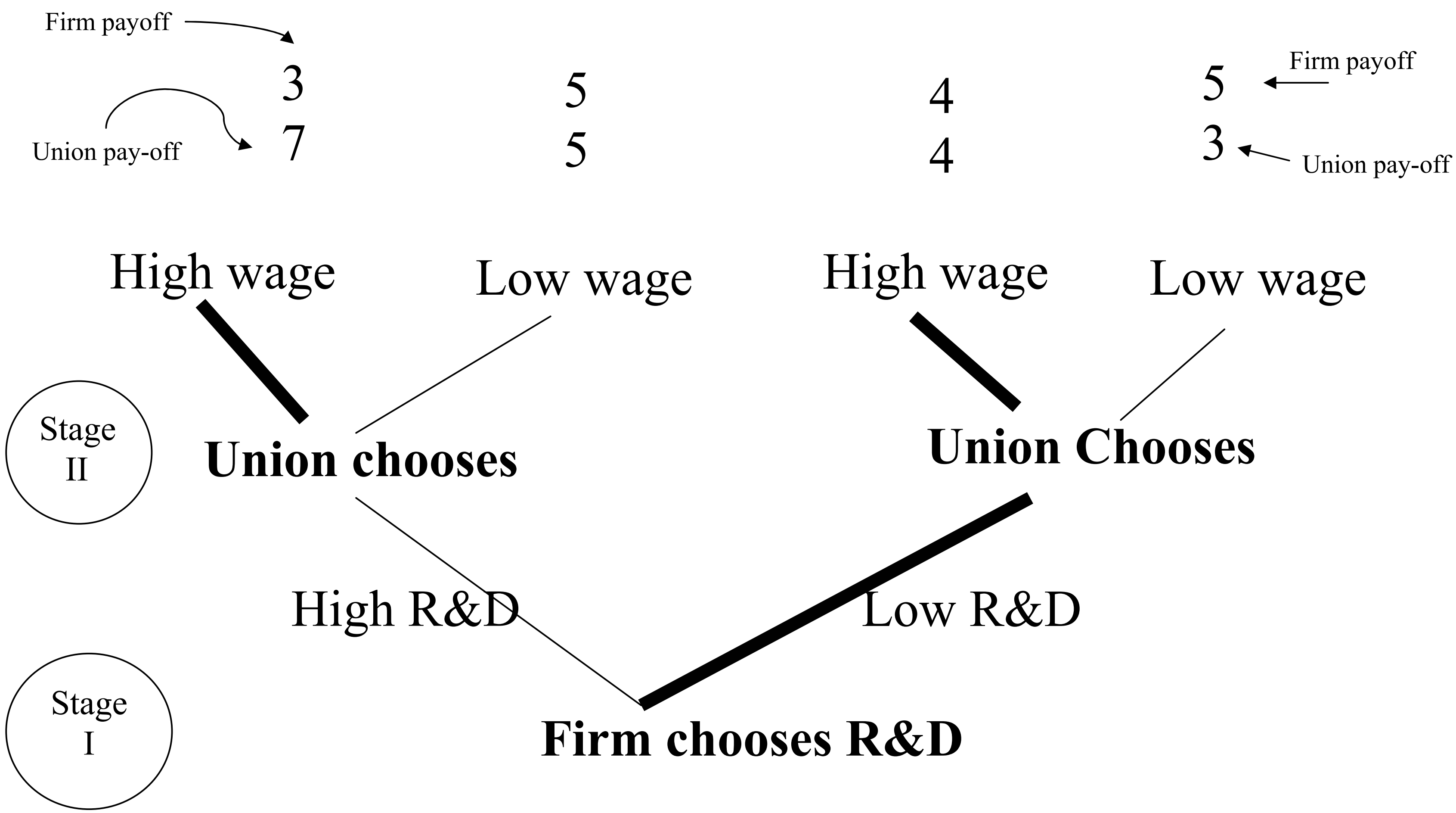
Table 5: Unions and Productivity Growth

Authors	Methodology	Data	Indicators of technical changes & unionisation	Controls	Results
Allen (1988)	Ordinary least squares	74 US industries (3 and 4 digit). 1972-83	Percentage of workers organized. Average output (physical units) per employee hour;	R&D, concentration	Insignificant negative (levels) Insignificant positive (changes)
Clark and Griliches (1984)	Ordinary least squares	924 US line of business 1975-79	Union recognition Real Sales	R&D, capital utilization, revenues	Insignificant positive
Freeman and Medoff (1984)	Ordinary least squares	79 US industries (3 digit): 1958-76 450 US industries (4 digit): 1958-78 State by Industry Cells: 1972-77	Percentage of workers unionised. Average annual value added per worker;	None	Insignificant negative
Gregg et al. (1993)	GMM (but unionisation treated as exogenous)	328 UK firms 1984-89	Union recognition. Real sales growth	*Firm Level:* Labor, capital, market share,	Between 1985-87 there is no union effect; between 1988-89 there is a positive and

				borrowing ratio, Competition *Industry level*: hours worked, price of Materials	significant union effect especially for firms that de-recognized unions and/or faced increased competition
Hirsch (1991)	Ordinary least squares	531 US firms between 1968-80	Firm-level union coverage in 1977. Real value added growth	*Firm Level:* Size, labor, capital, R&D *Industry level*: sales, energy usage, trade	Strong negative correlation; Remains negative after firm-level controls; Weakly negative after industry dummies; Insignificantly positive after correcting for firm specific serial correlation in the error term
Hirsch and Link (1984)	Ordinary least squares	19 US manufacturing industries (2-digit) 1957-73	Union density in 1958. Total factor productivity growth;	R&D/sales, market concentration	Negative effect of the levels and the changes in union density
Link (1981)	Ordinary least squares	51 major manufacturing firms in the US	Percentage of workers unionised. Avg. annual rate of change in total factor productivity.	Different measures of R&D	Negative (significant at 10%) impact of unions
Link (1982)	Ordinary least squares	97 US firms in the chemical, machinery and petroleum industry	Percentage of workers unionised. Avg. annual rate of change in total factor productivity.	Different measures of R&D	Negative impact of unions
Maki (1983)	Annual time series regression	US non-agricultural manufacturing sector between 1926 and 1978	Aggregate union membership (level and change). Total factor productivity growth.	Strikes, median education	Negative effect of the level of density (long term effect) and positive effect of change in density (shock effect).
Mansfield (1980)	Ordinary least squares	20 US manufacturing	Union density in 1953.	Different	Negative in all specifications

		industries (2-digit) between 1948-66.	Avg. annual rate of change in total factor productivity;	measures of R&D	
Menezes-Filho et al. (2002)	Ordinary least Squares	222 Brazilian manufacturing Firms	Firm-level union density in 2000. Real value added growth: 1995-2000.	Firm employment, capital, market share, product market competition, industry dummies	No Effect in the linear specification Strong evidence of non-linearity (positive at low density levels, negative at high density levels)
Nickell et al. (1992)	GMM (but unionisation treated as exogenous)	122 UK firms 1975-86	Proportion of manual employees covered by trade union agreement. Real sales growth.	Firm employment, capital, market share, borrowing ratio, industry concentration, import penetration	Between 1975-78 union effect is negative; between 1979-84 union effects is positive; between 1985-86 union effect is negative. All effects are significant
Nickell and Layard (1999)	Ordinary least Squares	20 OECD countries	Union density, union coverage, coordination of bargaining. Labor productivity, TFP;	Tax, employment protection, replacement rate, benefit duration	No effect in all specifications

Figure 1:Unions and R&D investment: The "Hold Up" Problem



Note to Figure 1:

This is the extensive form of a two-stage game. At stage I the firm chooses R&D (simplified to be either "high" or "low") and at stage II the union chooses wages (again either "high" or "low"). Solving backwards the union will always pick "high" wages at stage II. Knowing this firm will always choose a low R&D strategy (sub-game perfect equilibrium). This leaves union with pay-off of 4 and firm with pay-off of 4. Both parties would be strictly better off with a (high R&D, high wage) equilibrium where each party would receive a pay-off of 5. Unfortunately, although this is Pareto optimal it is not a sub-game perfect Nash equilibrium.

Endnotes

[1] This is suggested by the title of Addison and Hirsch's (1989) paper: the 'long-run' has arrived for US unionism.

[2] This may be a reason why unions are often in the forefront of lobbying for greater protection from foreign trade (they have a common interest with their employers in this regard).

[3] The original Luddites claimed to be led by one Ned Ludd, also known as 'King Ludd', who is believed to have destroyed two large stocking-frames that produced inexpensive stockings undercutting those produced by skilled knitters and whose signature appears on a 'workers manifesto' of the time. Whether or not Ludd actually existed is historically unclear. The movement spread rapidly throughout England in 1811, with many wool and cotton mills being destroyed, until the British government suppressed them harshly (including making 'machine breaking' a capital crime, and executing 17 men in 1813).

[4] Of course this will not always be the case. When Edison invented the phonograph in 1877 he envisioned several uses for it such as preserving the words of dying people, recording books for blind people, announcing clock time and teaching spelling. Other entrepreneurs created jukeboxes to use the phonograph but Edison objected this debasement of his invention. It was only after about twenty years that Edison reluctantly conceded that the main use of the phonograph was for recorded music.

[5] For example, an analysis of over 2000 establishments from the British Workplace Industrial Relations Survey (WIRS) concluded: 'Overall, our results showed, first, that when it came to the introduction of particular changes involving advanced technology at the workplace, the general reaction of the workers affected was favourable. Second, in the cases where either shop stewards or full time officers [i.e. union officials] became involved, they tended to support the change even more strongly than their members' (Daniel, 1987, p.264)

[6] See Arrow (1962) for a classical analysis of these problems.

[7] McDonald and Solow (1981) made this 'implicit bargaining' argument but Johnson (1990) showed that in the context of a formal theoretical model that wage and effort

bargaining would not reach the efficient bargaining solution (although it would get the partners closer to the Pareto Efficient outcome).

[8] Ulph and Ulph (2001) show that the incompleteness of the union/firm contract (that may induce under-investment in R&D) may actually compensate for the socially inefficient over-investments induced by the R&D tournament among firms (for the latter effect see Beath, Katsoulacos and Ulph, 1995).

[9] Or, more realistically, end with a small and commonly known finite probability in every sub-game.

[10] This is the model of Gilbert and Newbery (1982); formally it is a one-shot tournament R&D game with no uncertainty and two players.

[11] See Bond and Van Reenen (2002) for an overview of the investment and R&D literature. Structural models of unions and R&D would constitute interesting new research.

[12] For example see Carlin et al. (2002), Griffith et al. (2000) or Machin and Van Reenen (1998).

[13] Under the accounting regulation SSAP(13) Revised.

[14] See Bound et al. (1984) for an early discussion of this.

[15] Although there is the problem that budgetary cut-backs in the Patent Office can alter the time series of patents, so that it may take longer to get a patent granted (see Griliches, 1998). There is also the issue that the standard for patents may have slipped over time (such as the granting of patents for 'business process innovations', such as Amazon's 'click and pick' web-site).

[16] The EU has currently developed a program to measure firm level innovation using the Oslo definition, which is subjective. It is becoming more useful now, as it is possible to compare this measure over time.

[17] For a discussion over the interpretation of cash flow in R&D equations see Bond et al. (1999)

[18] This is equivalent to the 'within groups' transformation that involves subtracting the firm specific time series mean from each observation.

[19] This will be less of a problem for some measures like TFP or diffusion that show more time series variation. One must ask, however, whether the time series variation

in TFP is due to technology or other non-technology related factors such as the state of the business cycle.

[20] A disadvantage of their data is that they do not observe union density at the industry level, but have to predict density from industry characteristics using the coefficients from individual level union membership regressions.

[21] It introduces the method of conditioning on pre-entry stocks of innovation counts and with a non-linear dynamic GMM model with fixed effects.

[22] Borghans and ter Weel (2002) use unionization as an instrumental variable for wages in a computer use equation. Unfortunately, the absence of a significant correlation between unions and technology adoption (conditional on wages) does *not* guarantee the validity of this identification strategy.