APPENDIX: THE SELECTION CRITERION EQUATION

The CURDS data set contains detailed information on the level of ownership of CNCs by each firm in the sample incorporating date of first adoption. This allows us to classify the sample firms in 1993 into 4 categories: non adopters; currently diffusing users; complete users; and ex users. Of the total sample of 343 firms, 59 firms were excluded on the grounds that CNC was not an appropriate technology, of the remaining 284 eligible firms in 1993 there are ten ex users, four complete users, 208 diffusing users and 62 non adopters. The number of complete users and ex users is too small to enable us to statistically model the censoring due to their exclusion from the sample used for estimating the intra firm diffusion model and thus we just remove these observations and instead concentrate upon modelling the distinction between non adopters and firms diffusing in 1993[1].

We define the selection criterion equation of the state of the firm in 1993 via a latent discrete variable (z_{ijt}) taking the value 0 if the firm is a non adopter and 1 if it is a current diffuser. Such variable attributes a set of probabilities for the two possible states for firm i with respect to adoption of the technology expressed as a function of w_{it}, a vector of the determinants of first adoption. In statistical terms, the Selection criterion equation can thus be specified as:

$$z^*_{it} = \psi' w_{it} + u_{it}$$

$$z_{it} = 0 \quad \text{if} \quad k_{nit} = 0 \qquad \text{(Non Adopter in 1993)}$$

$$z_{it} = 1 \quad \text{if} \quad 0 < k_{nit} < 100\% \qquad \text{(Adopter and User in 1993)}$$

where u_{it}, a residual correlated by an amount ρ to the residual of the intra firm diffusion equation which may then be used to correct the latter from sample selection bias. The type of probabilistic model used to estimate the Selection criterion equation is determined by the distribution of the residual u_i, e.g. Probit or Logit. The specification of a Logit model would be supported by the inter firm literature that predicts that diffusion follows a logistic pattern over time (see for example Mansfield 1968). However, the cross sectional nature of technology ownership might just as well result in the Probit distribution. Empirically, we find that the Logit specification is preferred and thus we report only upon this.

[1] In order to explore the impact of excluding ex users and 100% users we have also undertaken some estimations in which they were included and looked at the impact upon parameter estimates. The results do not change significantly. This leads us to conclude that their omission does not significantly impact upon our findings and thus there is no significant censoring resulting from the approach employed.

In general, the variables to be included in w_{it} are the possible factors leading a firm to adopt a technology, these being classed generally as rank, stock, epidemic and order effects (see Karshenas and Stoneman, 1993). They reflect market and firm specific characteristics as well as spillovers and externalities from use at time t. However, as it was never the intention to fully model the inter-firm diffusion of new technology the actual selection criterion equation can be rather ad hoc. In fact very few of the variables considered as candidates for the selection criterion equation turned out to be significant. Moreover, these effects, with the exception of the order effect, do affect not only the adoption decision (selection criterion equation) but also the intra firm level of use of a new technology at time t (technology replacement equation). This might cause simultaneity problems and spurious significance of sample selection effects. Battisti (2000 and 2003) has shown that in the case of an irreversible choice such as the above, an ad hoc specification that explains 1993 adoption by variables dated at the time the decision was made for pre 1993 adopters, enables one to overcome causality problems and the lack of variability between the two steps of the model. In addition, this approach implicitly solves the truncation problem of the unobservable future decision to adopt after 1993 by a non adopters.

Our preferred ML estimates of the selection criterion equation are presented in Table A1[2], the sample used being of size 149 of whom 109 were diffusing CNC in 1993**.** Of the total sample of 343, 59 had been removed as the technology was not appropriate and 14 either ex users or 100% users. The sample was further reduced by missing values for variables due also to the retrospective nature of the information needed to specify the variable information set (w_{it}). The diagnostic indicators for the results are reasonable. The criterion for final inclusion of variables as determinants of ownership in 1993 was the performance of the selection criterion equation rather than any other. In fact very few of the variables considered as candidates for the selection criterion equation turned out to be significant. The variables included are as follows.

The rank, stock and order effects imply that the cost of acquiring the new technology either in 1993 or at the date of adoption and expected changes therein should impact upon whether the firm has acquired the new technology. We thus include the (log of) the price of CNC (LCNCprice), in 1993 for non adopters and at the date of actual first adoption for adopters, as

[2] In Table 1 the parameters are not the marginal effects but the estimated coefficients. Given that the emphasis is on intra rather than inter -firm diffusion, the discussion of the selection criterion equation is limited to the significance of the variables and not on their marginal impact.

measured by the log of the real quality adjusted price at the factory gate and expected changes therein as measured by actual changes in price (DCNCprice) at the date of adoption for adopters and in 1993 for non-adopters (see Battisti, 2000 for further details). The results indicate that the price of CNC impacts significantly (at the 5% level) and negatively as expected upon the probability of a firm being a user in 1993. The expected change in price although carrying the predicted positive coefficient is not significant.

Table A1. The Selection criterion equation

Variable (τ_o)	Coefficient	Standard Error	z-value	Probability
LCNCprice	**-2.018**	**0.822**	**-2.456**	**0.014**
DCNCprice	-0.97E-02	0.16E-01	-0.641	0.522
LSmallEMP	**4.774**	**1.423**	**3.354**	**0.000**
LMediumEMP	**4.217**	**1.182**	**3.566**	**0.000**
LLargeEMP	**3.159**	**0.823**	**3.840**	**0.000**
COTuser	-1.359	0.907	-1.499	0.134
Ncuser	**1.671**	**0.942**	**1.774**	**0.076**
MICROuser	0.359	0.999	0.360	0.719
CAPMuser	-0.961	2.040	-0.47	0.638
BS575user	**-5.408**	**2.241**	**-2.413**	**0.016**
JITuser	1.691	2.099	0.806	0.420
LSH1	-0.905	0.587	-1.542	0.123
LSH2	**-1.294**	**0.568**	**-2.276**	**0.023**
LSH3	**-1.430**	**0.637**	**-2.245**	**0.025**
LSH4	-1.928	1.699	-1.135	0.256
LSH5	**-3.018**	**1.052**	**-2.868**	**0.004**
LSH678	**-1.795**	**0.617**	**-2.908**	**0.007**
LSH9	**-2.297**	**0.749**	**-3.066**	**0.002**
LSH10	**-1.976**	**0.644**	**-3.067**	**0.002**
LSH12	**-1.208**	**0.626**	**-1.932**	**0.053**

Number of observations	149
Log likelihood function	-28.408
Restricted log likelihood	-86.676
Chi-squared (19)	116.53

The rank effects being firm specific are modelled by:

- *Firm size* measured by log of the number of employees (LE) at the time just before or nearest to first adoption or 1993 for non adopters (data are available for 1970, 1975, 1980, 1986, 1991, 1993**)** multiplied by size class membership dummies, reflecting three different size categories: less than 50 (LsmallEMP), between 50 and 500 (LmediumEMP) and more than 500 employees (LlargeEMP). As these are fully inclusive there is no other constant in the model.
- *Characteristics of the management at time of first adoption.* These are specified as dummy variables (CAPMuser, BS572user, JITuser) that take the value 1 if a managerial innovation had already been introduced at the time of first adoption of the advanced

technology or in 1993 for non adopters and zero otherwise. The innovations are: Computer Aided Production Management system, BS575/ISO 9000 accreditation and Just in Time methods.

- *Characteristics of the firm production system at time of first adoption.* This is defined by a series of dummy variables (COTuser, NCuser, MICROuser) that take the value 1 if, at the time of first adoption for adopters or 1993 for non adopters, the firm was using other advanced technologies, and 0 otherwise. The set of technologies included are: Coated Carbide or ceramic tools or inserts for metal cutting (CoT), Numerically controlled machine tools (NC) and Microprocessors incorporated into manufacturing production processes (MICRO).

The empirical evidence shows that the three firm size variables are all positive and significant but decrease with firm size. Of the dummy variables relating to the use of other technologies only that relating to NC technology is significant indicating that prior users of NC technology are more likely to become users of CNC technology. This might imply some sort of learning effect. Of the three management innovation dummies only whether the firm possesses the BS575/ISO 9000 accreditation impacts significantly and then negatively on the use of CNC.

Stock, order and epidemic effects are proxied by LSH_{kt}, (k = 1 …11), the log of the proportion of the firms using CNC in each of the industries in which the firm operates measured at the date of the firm's first adoption or 1993 for non users[3]. In the first two cases, the increasing number of users makes adoption less profitable and LSh should exert a negative impact upon adoption. If epidemic effects dominate, due to spillovers and non-pecuniary externalities LHS is expected to have a positive coefficient. The empirical evidence indicates that the dominant sign of the parameter estimates is negative, suggesting that use elsewhere slows adoption. We have also tried to include a variable measuring the number of years between first appearance of the technology and the date of first adoption by the firm (or 1993 for non adopters) as a further epidemic effect, but it was not significant.

[3] For each firm the data set reports the SIC classification up to three digits for 11 industries (1=MLH331, 2=MLH332, 3=MLH333, 4=MLH336, 5=MLH337, 9=MLH 341, 10=MLH361, 11= MLH390, 12=subcontractors, 13= MLH349, 15=other mechanical engineering). For one industry it provides the classification up to four digits (MLH33393/4 , MLH33391/2/5/6/7/8 and MLH3399). The latter, after appropriate testing, has been grouped into one industry defined D678.