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ABSTRACT

This paper describes the approach applied and the results of an evaluation of the effects of the Swiss government programme to promote the diffusion of Advanced Manufacturing Technologies (AMT) from 1990 to 1996. The method used is based on specifying and econometrically estimating with firm data simultaneously an *adoption equation* which, besides the main explanatory variables as proposed by the theory of technology diffusion, includes a policy variable, and a *policy equation* with a set of firm characteristics and an adoption variable as regressors. The results are consistent with a positive impact of promotion on adoption of AMT, particularly a more intensive adoption of AMT for firms which did not use AMT when the programme started.

1. Introduction

The importance of innovation and technology policy has considerably grown for most OECD countries in the last years. Such a policy covers a wide spectrum of activities, ranging from the direct support of basic reseach to more indirect measures aimed at improving the capability of firms to innovate and to use new technologies. Recently, new developments in technology policy with an increased emphasis on technology diffusion and adoption, organizational change and innovative behaviour have raised new methodological challenges for the evaluation of these policies (see e.g. OECD, 1997a and Georghiou and Roessner, 2000). Accordingly, there is an increased interest in OECD countries in the issue of evaluation of government programmes and policies. Evaluation issues are central to improving the effectiveness of policy and formulating „best policy practices" (see OECD, 1997b and 1998).

The main feature of Swiss technology policy is the low weight it places on direct measures for fostering innovation in the economy. It is primarily oriented towards creating a favourable environment for the introduction of new products and production techniques, whether such innovations rely on firm-internal research and development or on the adoption of novelties generated by other firms or institutions. This framework-oriented policy is supplemented by a number of specific measures to stimulate rapid diffusion of selected basic technologies which are considered to be relevant for a broad spectrum of industrial activities. A typical example of the last approach is a programme to promote the use of „Advanced Manufacturing Technologies" (AMT) launched in 1990 and ended in 1996. It offered the firms information and training services as well as subsidies for consultancy and development projects; the latter were in most cases based on joint ventures between firms or between firms and research institutions embedded in regional networks. The concept of this type of policy measures is to strengthen the firms' ability to undertake the techno-organizational adjustments necessary for successfully (and rapidly) adopting the new technology which, in the case of AMT, poses a challenge for many (smaller) firms of most industries.

This paper presents the approach applied and the results of an evaluation of the effects of this programme which is described in somewhat more detail in section 4. The method used is based on specifying and econometrically estimating with firm data simultaneously an *adoption equation* which, besides the main explanatory variables as proposed by the theory of technology diffusion, includes policy variables which discriminate government supported from non-supported firms, and a *policy equation* which contains a vector of factors influencing the selection procedure of supported firms (or, the other way around, the decision of firms to participate to the government programmes); the policy equation takes also account of firms' prior experience in the supported technology, thus including the dependent variable of the adoption equation as an additional regressor. The analysis is based on data of 463 firms (96 supported and 367 non-supported firms). Our results suggest that promotion did lead to a more intensive adoption of AMT especially for firms which did not use AMT when the programme started.

In section 2 we characterize our approach and point to some differences to other methods of evaluation. In section 3 we introduce the (theoretical) model of technology adoption underlying our investigation. In section 4 we describe the data base and some features of the diffusion process of AMT and the firms‘ use of the policy measures to be evaluated. In sections 5 the specification of the empirical model of adoption and econometric estimates are presented. The empirical confirmation of the adoption model is a necessary condition for a successful application of our model-based evaluation approach. Section 6 contains the specification of the policy equation and the corresponding econometric estimates. Section 7 is devoted to the policy evaluation in the narrow sense. We describe and discuss the results of the simultaneous probit estimation of the adoption and policy equation, each of them also including the dependent variable of the other one. We conclude by an assessment of the proposed procedure and some recommendations for evaluating specific policy measures.

2. Evaluation Concept and Econometric Implementation

The majority of evaluations of public support for technology diffusion in Switzerland is primarily directed to the efficiency of such programmes in a rather narrow sense. The topics covered by such evaluations are typically the following: Is the target group well informed on the support measures available? Do firms to which policy is targeted take part to a satisfactory degree? Are management and procedures of a programme efficient? What are the motives for participating? Are barriers of diffusion as perceived by firms sufficiently addressed by the policy measures? etc.[1] This type of evaluation, though useful, does not yield an assessment of the economic effects of diffusion-oriented measures, because it concentrates on 'programme immanent' performance measures and does not take account of firms not participating (no control group analysis).[2] Recently, an evaluation methodology based on econometric models with firm-level data has been proposed and partly applied on specific problems such as public support to business R&D, manufacturing technology centres, adoption of new technlogy, etc. (see e.g. Capron and van Pottelberghe de la Potterie, 1997; Jarmin, 1998 and Geyer *et al.*, 2000). Our evaluation concept is based on this type of methodology.

The present investigation is focussed on the results of policy intervention. More specifically, it is asked whether the primary goal of public support, i.e. a more rapid and broader diffusion of AMT compared to firms standing aside (i.e. the control group), is actually attained. However, we do not investigate the impact of the government progamme on firms‘ performance per se, which would imply a different analysis framework as the one used in this paper.

The envisaged type of evaluation requires an econometric analysis based on the theory of technology diffusion using micro-level firm data for a sample which contains supported firms as well as not-supported ones. More specifically, we estimate equations of technology adoption based on general factors determining the use of new production techniques as well as policy variables to identify the marginal effect of policy intervention.

Assumming that the goal variable (e.g. adoption of a certain technology) of a firm i in period t denoted $Y_{i,t}$ is determined by a vector of theory-based variables $X_{i,t}$ (e.g. diffusion theory) the evaluation procedure may be presented formally by

$$Y_{i,t} = \alpha_o + \beta_1 X_{i,t} + \beta_2 P_i + \textit{control variables} + e_{i,t} \qquad (1)$$

where P_i is a vector of policy instruments with takes some non-zero value for programme participants receiving policy support and zero for non-participants, control variables for the sectors or industries the firms belong to and $e_{i,t}$ is a stochastic term.

In equations of type (1) the impact of policy promotion is measured directly and can be interpreted straightforwardly based on the signs of β_2. If a policy measure aims at increasing Y, a positive (and statistically significant) parameter indicates an advantage of the supported firms over the non-supported ones with respect to the goal variable, a negative one shows a disadvantage.[3] In both cases we can derive clear indications with regard to the impact of the policy measures: a positive coefficient means that policy is effective in the direction targeted by policy makers; in the case of a negative sign the influence of policy runs opposite to the policy goals bringing promoted firms away from target. Consequently, statistically insignificant coefficients hint to an ineffectiveness of the policy instruments.

If enough randomness with respect to the allocation of policy support to firms and projects exist, data for the supported firms as well as for similar non-supported firms would provide the evaluator with a basis for causal, econometric analysis, because under these circumstances the statistical preconditions for this type of analysis (hypotheses on type of the distribution functions of residuals, etc.) would be fulfilled. However, given the many factors involved in the process of political decision-making that determines the allocation of policy support, random allocation seems a rather unrealistic assumption; in this case the evaluation results may be biased due to self-selection (see e.g. Maddala, 1983). Any evaluation procedure will have to take this problem explicitly into account.

In case that only *cross-section data* are available, the more widely-used selection-correction method introduced by Heckman (1979) can be applied, which is a *two-equation approach* built up on an equation of type (1) above and a selection equation. Based on assumptions on the joint distribution of the residuals of these two equations, the coefficient β_2 in (1) can be estimated by a simultaneous or a sequential approach. In this study we choose a *two-equation framework* by adding to the basic evaluation equation (1) a second equation explaining the policy variable P_i.

A particular advantage of this approach is that important features of the political economy of firm participation to government programmes can be explicitly taken into consideration in the evaluation procedure. However, there is no standard theory explaining whether or not a firm obtains support, because the selection procedure is mostly a specific one, depending not only on the priorities of government agencies with respect to some categories of firms to be especially supported (e.g. small firms, firms belonging to hightech sectors, etc.) but, among other things, also on the earlier experience of firms with other support programmes as well as with the technologies which are promoted by a certain programme (see section 6).

In this study two equations were estimated simultaneously, one for technology adoption A (goal variable) and a second one for government support P (policy equation):

$$A_i = \alpha_o + \beta_1 X_i + \beta_{2,i} P_i + \textit{control variables} + e_{i,t} \qquad (2a)$$

$$P_i = \gamma_o + \gamma_1 Z_i + A_i + u_i \qquad (2b)$$

where Z_i is a vector of factors influencing the selection procedure of supported firms or, the other way around, the decision of firms to participate to the government programmes. Further, it is reasonable to assume that firms with prior experience in the technology supported by policy measures could be more eager to participate to the technology programme than firms without such experience; thus, the second equation also contains the goal variable as regressor.

For this special version of a simultaneous probit model the estimation method was based on a "mean- and covariance-structure model" (Browne and Arminger, 1995) and was implemented in the software programme MECOSA 3 (Arminger, 1995). A two-step procedure (first, estimation of the coefficients of the reduced form of the original simultaneous equation system, then estimation of the structural parameters based on the covariance matrix of the reduced form coefficients) was applied to estimate the simultaneous probit model according to the algorithm implemented in the above-mentioned software.

3. A Model of Technology Adoption

The objective of this section is to formulate an equation explaining the decision to adopt some element(s) of AMT based on a set of mainly firm-specific factors determining the profitability of new technology. Our theoretical approach is based on the general framework proposed by Karshenas and Stoneman (1995). According to these authors the main (neoclassical) models of diffusion may be categorized in four groups (epidemic, rank, stock and order model) which can be fused to a „higher order model" containing the specific features of the differrent approaches.[4] Within this general conceptual framework our approach belongs rather to the category of „rank models" emphasizing the heterogeneity of firms as determinant of inter-firm diffusion patterns. In this view it is assumed that potential users of a new technology differ from each other in important dimensions so that, at a certain point in time, some firms obtain a greater return from new technology than others do. The larger the net advantages resulting from the technology adoption, the stronger the tendency to adopt this technology earlier and more intensively.

We distinguish several groups of factors which potentially influence (positively or negatively) a firm's profitability from adopting new technology and therefore the decision to introduce it at a certain time. A first one includes a set of anticipated benefits of new technology such as savings of inputs, general cost reductions, higher flexibility, improvement of product quality, etc. (see e.g. Clark, 1987 or Milgrom and Roberts, 1990 for theoretical treatments of this aspect). The new technique may save labour or some specific labour skills; it may reduce capital needs, for example, through increased utilization of equipment, reduction of inventories or space requirements, etc. It may also lead to higher product quality or better conditions for product development. Moreover, it may increase the flexibility of the production process allowing the exploitation of economies of scope. For this group of variables we expect a positive influence on the adoption decision (i.e. early and intensive use of new technology is favoured).

A second category of variables refers to anticipated barriers to the adoption of new technology (see e.g. Cainarca et al., 1990). We identify four main types of such hindrances: financial (e.g. general liquidity constraints, cost of new technology and manpower training) and human capital restrictions (e.g. lack of engineers and technicians); informational and know-how barriers (e.g. uncertainty with respect to the performance of new technology or the utilization of new production capacity); organizational and managerial barriers (e.g. resistance to new technology within the firm; insufficient attention of the management) and sunk costs barriers; the latter refer to the high substitution costs firms have to incur in order to introduce the new technology, for example, in case of insufficient compatibility of new technology with existing equipment, existing organization or existing product portfolio (see e.g. Link and Kapur, 1994). We expect such barriers to be negatively related to adoption.

A third category of explanatory variables is related to the (product) market conditions under which the firms are operating, particularly the competitive pressures they are exposed to. Mostly, market concentration, a structural variable, is taken to reflect competitive pressures. In the game-theoretic literature the impact of market structure upon the schedule of adoption dates is shown to depend critically on the difference of profit rates preceding and following adoption (see e.g. Reinganum, 1981). This dependence being quite complicated, most studies do come to theoretically ambiguous results with respect to the effects of market concentration on adoption (see Reinganum, 1989 for a review of this literature). Thus, whether positive effects in the tradition of Schumpeter are stronger than negative „free competition effects“ has to be resolved at the empirical level. Therefore, we make no prediction concerning the sign of the concentration effect. Another line of thought argues that it is the elasticity of demand faced by a firm in its specific market that induces innovative or imitative activity (see Kamien and Schwartz, 1970 for the original argument). In those markets where competition pressure is greater, demand elasticities can be expected to be higher because of the existence of close substitutes, thus driving firms to innovative activity or rapid new technology adoption (see e.g. Majumdar and Venkataraman, 1993). In accordance to this line of reasoning, we have proxied in an earlier study on the determinants of process innovation competitive pressures through the intensity of price and non-price competition at the product market and postulated a positive relationship to innovative activity (see Arvanitis and Hollenstein, 1994); we apply the same argument for new technology adoption.

A further group of variables serves to characterize a firm‘s products and production technique. The main idea is that product type and existing production technique of a firm play an important role in determining extent and limits of the use of AMT (see e.g. Taymaz, 1991 and Evers et al., 1990). On the product side, it is expected that the benefits from applying AMT in producing differentiated goods would be rather small as compared to standardized ones; therefore, a negative impact of (the degree of) product differentiation is expected. With respect to production technology a positive relationship between the „length of production run“ and adoption is postulated, because AMT can fully unfold its potential primarily in plants with large-batch or mass production („scale effects“). The development of more sophisticated AMT during the last decade, however, favoured production flexibility, thus enabling firms to adapt quickly and efficiently to external or internal changes. This „flexibility effect“ works in the opposite direction to the (traditional) „scale effect“ thus weakening the overall influence of variables characterizing the type of product and process technology on AMT adoption.

The firm’s ability to absorb knowledge from external sources and exploit it for its own innovative activities is a major determinant of innovation performance in general and of technology adoption in particular (see Cohen and Levinthal, 1989 or, specifically for the case of AMT adoption, Baldwin and Rafiquzzaman, 1998). We consider two important aspects of a firm‘s absorptive capacity: firstly, the firm’s (overall) ability to assess technological opportunities in (or around) its fields of activity which depends primarily of the endowment with human and knowledge capital, and, secondly, the embedding of the firm in knowledge networks facilitating access to information and resources relevant for technology adoption. Both elements of absorptive capacity should be positively related to (early and intensive) use of AMT.

Finally, firm size, an explanatory variable used in most studies of adoption behaviour (see Karshenas and Stoneman, 1995), is also included in the present study; it is expected to be positively related to adoption.

4. Database and some characteristics of adoption and promotion of AMT

The analysis is based on firm data collected in the course of the Swiss Innovation Survey 1996 as a supplement to the standard questionnaire, thus allowing the combination of AMT-specific information with basic data on innovation and technology use. The available variables are to a large extent qualitative in nature, i.e. categorical or ordinal measures (mostly on a five-point Likert scale). As far as AMT is concerned the questionnaire yields data on the time profile of the introduction of nineteen AMT-elements, the linking of these technologies, the assessment of a whole series of objectives pursued by introducing AMT as well as the significance of factors impeding its application, the impact of AMT on competitiveness, employment requirements and organizational structure and, finally, information on government promotion of AMT.[5]

The survey has been addressed to manufacturing firms based on a sample stratified by industry (17 2-digit industries) and firm size (3 industry-specific size classes) with full coverage of the upper size class in each industry. Additionally, the questionnaire was sent out to firms not belonging to this panel which had participated to the programme of AMT promotion. The response rate has been about 34% with a somewhat higher percentage for non-panel firms. 80% of the respondents used at least one AMT element in 1996 with a median AMT-intensity of seven technologies and 20% have got promoted by one or more element(s) of the government support programme. The final data set used in the econometric estimations contains 463 firms (all of them already using AMT in 1996 or planning to use it up to 1999), fairly representative for the manufacturing industries and firm size classes in the original sample (see table A.1 in appendix I).

Owing to limited resources we could not perform a non-response analysis, so we cannot exclude that some kind of selectivity bias as to the adoption behaviour of the responding firms may exist in our data. However, we minimized the risk of being confronted with this kind of bias by building our empirical analysis not on the (presumably biased) information on adopting AMT in general, but on the specific use of some AMT elements for firms already being an adopter of AMT (see section 5).

Table I contains some information on the adoption rates of 19 elements of AMT in Swiss manufacturing since 1990 (including planned application of these technologies till 1999 as assessed in fall 1996 when the data was collected). The adoption rate (percentage of firms using a certain technology) in 1999 and the diffusion velocity (percentage increase of the share of firms using a certain technology element in the period 1990-1999) varies quite strongly among the technology elements listed in table I. For example, the diffusion of CNC machines being already an „old“ technology (the first use in our sample dates back to 1968) was quite high already in 1990 and changed „only“ by about 35% between 1990 and 1999. At the other extreme, „new“ technologies such as „simulation, rapid prototyping“, FMS or inter-company computer networks (ICCN) were used only by a small fraction of firms in 1990 but this share quadrupled until 1999 in the first two cases and increased by factor 14 in the case of ICCN.

In the late eighties it was a widespread view among industrialists and policy makers in Switzerland that the adoption of AMT was slower in Swiss industry than in many other countries (especially as far as SMEs were concerned). The experts preparing the promotion programme identified serious knowledge deficits with respect to the potential of AMT, the use of these technologies in the narrow sense as well as its interaction with the organization of production (see CIMEX, 1988). Therefore, it is not surprising that deficiencies with respect to (highly) qualified manpower was seen as the crucial bottleneck hampering the diffusion of AMT. In addition, the experts were convinced that part of the problem was the weak interaction between polytechnics and firms, particularly SMEs. Based on this appraisal following guidelines were formulated for the promotion programme: first, the programme had to take into account the interrelatedness of technical, organizational and human (knowledge) aspects of the adoption of AMT; second, promotion should take place at the regional level to make use of local spillover potentials[6] and lead in the long run to an increase of networking among firms and among firms and research/education institutions; thirdly, the programme should only help to overcome bottlenecks in the early phase of adoption, therefore it was to avoid that expectations of permanent subsidizing would arise.

In order to operationalize its concept the government agency in charge initiated seven regional AMT centres which started to work in 1990. Usually a (regional) polytechnical institute (or a network of such institutes) was the nucleus of such a centre to which different types of actors (leading companies, experts, consulting firms, etc.) were connected. The programme consisted of three types of measures which were either directly delivered or arranged by the AMT centres: first, information and training ranging from „one day information“ up to „two years full-time training courses“; second, consulting aiming either at supporting the realization of a specific AMT project or – more often – at preparing the introduction of AMT in a firm by means of an analysis of its specific needs and potentials for this technology which led to the formulation of an „adoption plan“ integrating technical, organizational and training aspects. Third, the programme subsidized also development projects in the field of AMT typically based on joint-ventures of firms with polytechnical institutes (where the firms had to bear at least 50% of the project costs). The programme ended in 1996 with the majority of the AMT centres being integrated in (groups of) polytechnics.

Table II contains some information on the extent of government support of AMT in the period 1990-1996 by industry and firm size. About 20% of the firms in the final data set have been supported by some element of the AMT promotion programme. Subsidizing of R&D projects connected with the introduction and/or extension of AMT has been the type of support most frequently applied for (60% of the firms); training and consulting services were claimed by about two fifths of the firms respectively. There are considerable differences among industries and firm size classes with respect to promotion frequency and mode of promotion. Not surprisingly, mechanical engineering/vehicles and electrical engineering/electronics having a very high potential for AMT use benefited most from government support. For these industries promotion was concentrated primarily in R&D projects, whereas in metalworking and other industries the support was focussed on consulting and, somewhat lesser, on training schemes. Very small (less than 50 employees) and large firms (more than 500 employees) have received AMT support more frequently than medium-sized firms. There is also a close relationship between mode of promotion and firm size: small and large firms received more-than-average support in R&D, medium-sized ones in training; firms with up to 200 employees were stronger promoted through the offering of consulting services.

5. Specification and Econometric Estimation of the Adoption Model

The Model

Throughout the paper we use an ordinal measure of the change of the AMT intensity between 1990 and 1996 (DAMTINT) as adoption variable. Thus, we implicitly presume that government promotion became effective already during the first year. The AMT intensity is measured as the number of technology elements (out of a list of 19 such elements in table I) in use in a firm in a certain year. We constructed a three-level ordinal variable which contains the following categories: no change or change by 1 AMT element (29.9% of the firms which had adopted at least 1 AMT element till 1996); change by 2 to 4 elements (45.2% of the adopting firms); change by more than 4 elements (24.9% of the adopting firms). A sensitivity analysis was conducted with a two-level and a four-level ordinal variable; both of them yielded virtually the same results with respect to the explanatory variables as the three-level variable. We chose the three-level variable on grounds of a better statistical fitting. By defining the adoption variable as a measure of intensity change we avoid to some extent identification problems which arise, first, because we do not know which specific technology is supported in every single case of promotion and, secondly, we do not dispose of data for the explanatory variables which are diffentiated by technology and time.

In concordance with the theoretical discussion in section 3 we distinguish several groups of explanatory variables (besides one adoption-specific control variable and four industry dummies; see table III). A first group of determining factors refers to objectives of and motives pursued by the firms for the adoption of AMT which we interpret as proxies for anticipated revenue increases due to the use of new technology.[7] The six metric variables listed in table III under the heading 'objectives/motives' are the factor scores resulting from a principal component factor analysis of 26 single objectives of AMT included in the questionnaire (see table A.2 in appendix I). Two of these factors are related primarily to expected product improvements (QUAL, DEV) covering a wide spectrum of possible gains from AMT use such as higher product quality and variety, introduction of „intelligent“ products, higher flexibility at the market as well as improved conditions for the development of new products. Another two variables seem to be connected more closely to expected changes in the production technique: various sources of productivity gains related to the introduction of AMT as mentioned in technical literature are reflected by the variables COST (labour saving; capital saving, i.e. reduction of inventories and space requirements, higher utilization of equipment, shorter production time, etc.) and FLEX (higher flexibility of work organization, flexibility within the firm in general, etc.). A fifth factor (BEST) refers to anticipated revenue potentials as a result of securing technological competitiveness (technology lead, keeping to „best practice“, etc.). For these five variables covering several aspects of potential benefits arising from applying AMT we expect to find a positive influence on the adoption variables. The sixth factor (FINCOMP) has a somewhat different character and cannot be linked directly to revenue increases. It contains elements of a „defensive“ adoption strategy (making use of favourable conditions for financing AMT introduction; competition pressure manifested through declining market share; etc.). It is not obvious whether these motives lead to early or late technology adoption; thus, the sign of the coefficient of this variable is a priori undetermined.

A second group of variables is related to factors impeding AMT adoption. Again six metric variables were constructed by a principal component factor analysis of 26 impediments to adoption (measured on a five-point Likert scale), which can be interpreted as proxies for several types of anticipated adjustment costs (related to the introduction of AMT) probably leading to late (less intensive) adoption (see table A.2 in appendix II). Thus, we expect a negative sign for these variables covering all categories of obstacles identified in section 3: INVCOST and KNOWPERS reflect costs/financial barriers and risks and impediments due to the lack of qualified personnel respectively, TECH and UTILIZ mostly informational and know-how barriers, RESIST organizational and managerial weaknesses, and COMPAT stands for obstacles related to sunk costs (several types of incompatibility).

A third category of explanatory variables represents conditions on the firm-specific product markets: intensity of price and non-price competition (IPC and INPC; measured on a five-point Likert scale); market concentration (CONC; three dummies for firms confronted with markets with varying numbers of competitors). We expect a positive sign for the two variables measuring the intensity of competition, whereas the influence of the market concentration can be positive or negative.

Next we hypothezise that the degree of product differentiation and the „length of production run“ exert an influence on adoption, which should be negative in the first case and positive in the latter. Product differentiation is measured by two dummies (0,1) representing the production of customer-specific (PDUSER) or otherwise differentiated products (PDMARKET) with standardized products as reference group. The „length of production run“ is proxied by three dummies (0,1) which stand for small-batch (SBATCH) and large-batch (LBATCH) as well as mass production or continous flow production (CONTFLOW) with single-piece production as referende group. We already mentioned that the flexibility potential of more recent vintages of AMT could weaken the overall impact of these two groups of variables.

The firm’s ability to absorb knowledge from external sources, which we expect to be positively related to early/intensive adoption, is measured by two variables: HUMCAP, the share of employees with qualifications at the tertiary level, should capture the overall ability of the firm to assess technological opportunities of AMT, whereas COOP, a binary measure of R&D cooperation (yes/no), stands for the advantages in adopting AMT by being integrated in knowledge-related networks of innovative firms and research institutions.

Firm size (SIZE), which should be positively correlated with AMT adoption, is specified as a polynom with respect to the number of employees (linear L and quadratic term L^2; see table III).

Finally, we included the AMT intensity in 1990, the start year of the promotion programme, (INT90) some industry dumies as control variables.

Econometric Estimate

Table IV contains the ordered probit estimates of the adoption equation (DAMTINT as dependent variable) based on 463 observations (total sample) for firms having adopted at least one AMT element. The coefficients of an estimate of the full technology adoption model as specified above are listed in column 1. Column 2 contains only those coefficients which were statistically significant at the 10%-level (restricted model). A circumspection of the results in column 1 and 2 shows that the estimates are robust.[8]

The main contribution to the explanation of adoption behaviour (in addition to the control variables) comes from three groups of variables: objectives of adoption of AMT reflecting anticipated revenue increases related to the application of AMT, capacity to absorb external knowledge and firm size.

Four out of six variables representing the influence of adoption objectives yield the expected positive and statistical significant coefficients, one of them (FINCOMP) a negative one. The variables FLEX („higher flexibility") and BEST („remaining on top of techological improvements") seem to have the largest weight among these variables. Among the anticipated benefits those related to factor-saving or flexibility-enhancing improvements of production processes (COST, FLEX) are more important than those referring to expected gains on the product side (DEV, QUAL). We could not find any significant effect for the variables reflecting adoption impediments except for INVCOST („high investment costs of new technology") which yielded a statistically significant negative coefficient.

In accordance with earlier results for the innovation behaviour of Swiss manufacturing firms the variables reflecting market conditions show no significant influence on adoption behaviour (see Arvanitis and Hollenstein, 1994); in the case of the variable for market concentration (CONC) this result probably reflects the countervailing effects mentioned in section 3 above.

The modes of existing production technology and existing types of products do not seem to play a major role for explaining the change of the intensity of AMT use; only firms with medium-/large-batch production (variable LBATCH) adopt, as expected, AMT more intensively than other firms. There are two contrary effects (scale economies vs. flexibilty possibilities) affecting the overall influence of these variables which seemingly counterbalance each other.

The variable COOP (dummy for R&D cooperation) used here as a proxy for the ability of a firm to absorb new technological knowledge exerts a significantly positive influence on the change of the intensity of AMT absorption; for the variable HUMCAP we find also a positive but not statistically significant effect.

As far as firm size is concerned the linear term is positive and statistically significant in both model versions. There is some evidence that adoption intensity is increasing less than proportionately with firm size but it is rather weak (negative coefficient of L^2 in equation (1)).

Finally, we obtained a negative coefficient for the control variable INT90. Moreover, we found positive and statistically significant coefficients of the dummy variable for chemicals/plastics (also for electrical machinery/electronics in the restricted model in equation (2)).

In sum, the anticipated new revenue potentials are seemingly much more relevant for the firm's decision to adopt (or intensify the use) of AMT than the costs which are associated with the introduction and adjustment of these new technologies to a firm's specific needs. A high capacity to efficiently absorb and apply new knowledge supports an earlier and/or increasing intensity adoption of AMT. Financing the investment for the new technology is found to be a problem especially for small firms causing a postponing of the adoption of AMT. Large firms seem to have a general advantage over small ones.

6. Specification and Econometric Estimation of the Policy Equation

To model the impact of government AMT promotion (policy effect) we constructed a variable based on a firms' assessment of the overall stimulus of government support on a five-point Likert scale (computed as a mean of the reported stimulus in each of the three types of activities – training, consulting, R&D projects – reported here; see appendix II for the exact wording of this question in our questionnaire). These stimulus measures were subsequently transformed to a binary variable (CIMTHM; value 0 for stimulus of 1 or 2, value 1 for stimulus of 3 to 5 („high stimulus") on the original five-point scale).[9] This binary variable has been used throughout in this study.

A policy equation was specified on grounds of „ad hoc" plausibility arguments. Specifically, several firm-specific factors were taken into consideration. First, firm size was inserted as an independent variable in the equation. Small firms may have a larger incentive to claim such support than large ones because of limited financial resources; moreover, the promotion of small firms has been an explicit goal of the Swiss AMT programme.[10] Thus, we expect a negative correlation of the policy variable with firm size. Second, industry dummies were used as control variables. Third, we considered two institutional characteristics of firms which may be related to the probability of being supported by a government programme: status as affiliate or parent-house and status as affiliate of a foreign enterprise. Although it is not a priori clear in which direction these variables could influence the policy variable, it seems reasonable to control for these institutional characteristics. Fourth, firms confronted with serious problems of financing innovation projects would be more inclined to claim government support than other firms. We constructed a proxy for „limited financial resources for developing/adopting new technology" by computing the mean of the assessments of the responding firms with respect to five impediments of innovative activity related to financial problems (measured on a five-point Likert scale).[11] We expect a positive sign for this variable. Finally, we included a dummy variable measuring the previous experience of a firm with other government technology promotion programmes. We expect a positive sign also for this variable because of the greater awareness of such firms of the benefits of technology promotion and the bettter knowledge of the administrative procedures in applying for policy support.

Probit estimates of the policy equation are found in table V. Accordings to these results there is only a weak negative relation between firm size and the probability of being a government-supported firm; the coefficient of L is not statistically significant. Important factors which correlate positively with the probability of goverment support are the lack of financial resources and, partly, previous experience with government support in other programmes and the status of being an affiliate of a foreign enterprise. The effect of industry dummies is negligible (except for the metalworking industry).

7 Econometric Estimation of the Simultaneous Model and Policy Evaluation

We estimated a simultaneous probit model with an adoption and a policy equation, each of them containing as additional explanatory variable the dependent variable of the other one (see section 2). We conducted the simultaneous estimation only with the independent variables which in the single equations in tables IV and V resp. yielded statistically significant coefficients at the 10%-level (restricted models in column 2 of both tables). Columns 1 and 2 of table VI contain the estimates of the simultaneous probit model based on all available observations („total sample"; N=463). Columns 3 and 4 show the estimates of the model using only a sample of those firms which at the launching of the promotion programme in 1990 did not yet apply AMT in production („reduced sample"; N=330). Testing for the policy effect with the reduced sample is thus more restrictive than testing it with the total sample.

The basic pattern of the model estimates for both equations is the same as in the single equations (adoption and policy equation in tables IV and V resp.) indicating a certain robustness of the underlying relationships. The coefficient of DAMTINT (adoption variable) in the policy equation is positive but for both samples not statistically significant at any relevant test level (columns 2 and 4). We could thus not find any evidence that the firms supported by the policy measures were those who were able to intensify the use of AMT stronger than non-supported ones in the period 1990-96. For policy evaluation the relevant estimation result is related to the effect of the variable CIMTHM in the adoption equation (columns 1 and 3). For the total sample no significant influence of the policy variable on adoption intensity could be found. In the estimates based on the reduced sample (only firms which adopted AMT for the first time after 1990) the coefficient of CIMTHM (policy variable) in the adoption equation ist positive and statistically significant (10%-level). This result for the more restrictive case amounts to a clear hint that participation to the government programme may have contributed to a more intensive adoption of new technology in the case of supported firms relative to non-supported ones. Therefore, government promotion has been to some extent effective, especially for firms using AMT for the first time, which was one of the goals of the programme.

The policy effect is significant also in estimates not shown here which were based on the subsample of small firms with less than 200 employees. On the contrary, we could not find a significant policy effect for the subsample of large firms (200 and more employees). In futher estimations for stimulus variables differentiated by type of support (training, consulting, R&D projects) not presented here we found similar results for information/training and consulting. In the case of R&D-support we obtained a statistically significant positive coefficient of the policy variables only for the subsample of firms with less than 50 employees (see Arvanitis *et al*. 1998, ch. 6).

8. Conclusions

This paper applies a procedure of analyzing the impact of public promotion of AMT on the intensity of diffusion of such technologies based on the simultaneous estimation of an adoption equation specified within the framework of standard diffusion theory and a policy equation capturing important aspects of the selection procedure of supported firms. The firm data used in this study were collected especially for this evaluation.

According to our results the most important factors influencing the adoption behaviour of a firm are, besides industry effects: positively, a series of anticipated new revenue potentials (e.g through cost reduction, higher flexibility, etc), the high capacity to efficiently absorbing and applying new technology and firm size; negatively, investment costs which are associated with the introduction and adaption of these new technologies.

What about the effectiveness of the Swiss government programme to promote AMT? The evidence suggests that the policy goal to foster the diffusion of AMT was attained in the case of firms adopting AMT for the first time or characterized by a low intensity of AMT use (and for small firms with less than 200 employees with some overlapping between these two categories).

The main advantage of our approach (and of microeconometric approaches in general) relative to alternative methods is, on the one hand, the explicit formulation, based on economic theory, of causal relationships between the goal variables of a policy support programme (in this case: the change of the intensity of technology adoption) and the factors, including policy instruments, influencing these goal variables. On the other hand this approach takes explicitly account of factors related to the political economy of the selection and participation respectively of firms with respect to the support programme in question.

The most serious shortcomings of our analysis (and of microeconometric methods in policy evaluation in general) are related to data limitations. Mostly, the evaluators do not dispose of time series of data from "before to after" the policy support programme or only data on a few variables not allowing an adequate modelling of the underlying relationships. Further problems may arise if adequate economic theory is lacking in the fields covered by an evaluation.

Keeping the definition of the goal variable rather *narrow* (in this case we used the narrow *intermediate* goal of public support of a more rapid and broader diffusion of AMT instead of the rather broad *final* goal of the programme of enhancing the performance of the participating firms, e.g. in terms of productivity, etc.) may be helpful in tackling such problems. Taking broader goals into consideration would often involve a two- or three-stage modelling and/or the explicit consideration of externalities.

In spite of the shortcomings of the microeconometric evaluation approaches sketched above there are still many advantages on their side which force us to consider them a core element of policy evaluation. Improvements of the database would significantly increase its reliability because most of the weaknesses of the approach lie at the empirical level. Therefore, it is crucial that the preconditions for an evaluation should be secured from the very beginning of policy implementation, i.e. at the preparatory stage of a promotion programme. This means, among other things, that the institutions responsible for policy implementation should be obliged to collect the necessary data and have the authority to enforce the participating firms to deliver the required information.

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Notes

[1] This is by far not only for Switzerland the case. Typical examples for Switzerland are Freiburghaus *et al.* (1990) who evaluated the promotion of joint research of universities and firms, and Balthasar et al. (1997) who assessed the effectiveness of the Swiss participation in technology programmes of the EU; for Austria see, for example, Polt et al. (1994) who assessed the public support measures for the introduction of AMT. A recent report by OECD (1995) with respect to the diffusion of information technologies in SMEs, drawing on a number of country studies, is also primarily based on this type of evaluation, which does not sufficiently take account of economic performance measures or changes of technology adoption (an exception, to some extent, is the country study „Canada"). See OECD (1997b) for an assessment of the state of the art in technology evaluation and Shapira et al. (1996) for a survey of the evaluation praxis in the United States.

[2] The same type of critique was put forward by Stoneman and van Diederen (1994) for the United Kingdom: „The DTI in the United Kingdom, for example, legitimates its diffusion policy with reference to market failure but evaluates its diffusion programmes predominantely in terms of the efficiency of their management, the accuracy of targeting, the appropriateness of their tool mix and the appreciation of the recipients of information." (p. 928).

[3] The argument runs the other way around if a policy measure aims at decreasing Y.

[4] For a recent review of the literature on the theory of technology diffusion in general see Sarkar (1998).

[5] The questionnaire is available in German, French and Italian and is available on request or can be downloaded from *www.kof.ethz.ch*.
[6] The importance of such regional effects is confirmed by a recent econometric study of the adoption of CNC machines and microprocessors in the UK (Baptista, 2000).
[7] Such an interpretation can be justified on ground of some evidence on the degree of the attainment of the pursued firm objectives related to AMT adoption (measured on a five-point Likert scale): about 48% of the firms having adopted AMT reported a (very) high degree of attainment of their objectives; some 40% of them reported a middle degree of attainment and only 12% of the AMT adoptors answered that their degree of goal attainment had been (very) low (see Arvanitis *et al*., 1998, ch. 4).
[8] See Arvanitis and Hollenstein (2001) for a full account of the results of the econometric estimation of the adoption model used in this paper.
[9] Overall 26% of promoted firms report a „high" policy stimulus; the corresponding figures for training, consulting and R&D are 28.9%, 22.7% and 15.0% respectively.
[10] One could also argue the other way round stating that large firms have better chances to get government subsidies than small ones because they can spend more in lobbying and have possibly greater experience in this field. However, we use a specific variable to cover „promotion experience", thus we expect that with respect to firm size the „small firm effect" will dominate.
[11] These impediments are: high innovation costs, long pay-back period for innovation projects, lack of internal and external financial resources and high tax burden.

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TABLE I

Adoption of Advanced Manufacturing Technologies (AMT) (Percentage of manufacturing firms; 1999: planned adoption)

Technology Element	1990	1993	1996	1999
Design				
Computer-aided design and/or engineering (CAD/CAE)	37.3	50.6	57.0	60.8
Computer-aided design/manufacturing (CAD/CAM)	23.3	34.4	42.5	47.8
Simulation, rapid prototyping	2.6	5.0	7.7	11.4
Planning				
Digital firm data recording	32.2	40.1	48.7	64.2
Computer-aided (manufacturing) planning (CAP)	32.9	40.8	50.7	62.9
Fabrication				
Computer numerically controlled machines (CNC/DNC)	40.6	48.9	52.8	55.0
Materials working lasers	5.7	8.8	10.7	13.1
Pick-and-place robots	14.2	19.9	23.2	26.7
Complex robots	5.3	8.1	11.8	13.4
Flexible manufacturing cells (FMC)	6.1	10.1	13.8	20.0
Flexible manufacturing systems (FMS)	4.2	8.6	13.1	18.8
Handling				
Automated storage and retrieval systems (AS/RS)	17.8	25.0	32.2	41.5
Transport systems (AGVS)	6.4	10.8	13.2	16.5
Quality control				
Quality control (CAQ) on material	14.5	22.4	28.7	41.2
Quality control (CAQ) on final products	14.2	21.9	30.0	42.8
Communication				
Local area network (LAN) for technical data	16.2	25.9	36.2	47.1
Local area network (LAN) for factory use	13.6	22.2	31.8	44.1
Production planning systems (PPS)	31.8	41.9	54.8	67.3
Inter-company computer networks (ICCN)	2.6	6.6	15.8	37.3

TABLE II
Government Promotion of AMT

	All firms	Government-supported firms		Type of government support		
				T	C	R&D
	N	N	%	(% of supported firms)		
Total manufacturing	463	96	20.7	37.5	43.1	60.2
Groups of Industries						
Metalworking	99	23	23.2	43.5	62.5	43.5
Machinery/vehicles	101	28	27.7	25.8	34.5	76.7
Electr.machinery/electronics	95	25	26.3	32.1	25.0	71.4
Other industries	168	20	11.9	54.6	57.1	40.9
Firm size (number of employees)						
less than 50	83	22	26.5	18.5	53.9	63.0
50-99	87	13	14.9	50.0	61.5	66.7
100-199	127	20	15.8	55.0	57.9	45.0
200-499	100	20	20.0	55.0	31.6	31.6
500 and more	66	21	31.8	24.0	20.0	88.0

Note: T: training; C: consulting; R&D: R&D projects.

TABLE III:
Specification of the Adoption Model

Variable	Description	Sign
Dependent Variable		
DAMTINT	Change of the AMT intensity (i.e. number of AMT elements used) in the period 1990-1996	
Independent Variables		
1. Objectives of/motives for the adoption of AMT		
(Scores of a principal component factor analysis of 26 objectives of AMT; six factors)		
FINCOMP	Favourable financial conditions; competitive pressure	?
COST	Cost reduction	+
FLEX	Higher flexibility	+
DEV	Improving product development	+
QUAL	Better product quality	+
BEST	Securing technological lead / “best practice“	+
2. Impediments to the adoption of AMT		
(Scores of a principal component factor analysis of 26 barriers to AMT ; six factors)		
TECH	High technological costs / uncertainties	-
KNOWPERS	Lack of knowledge / lack of adequately qualified personnel	-
RESIST	Resistance to new technology within the firm	-
INVCOST	High investment costs	-
UTILIZ	Uncertainty with respect to capacity utilization	-
COMPAT	Compatibility problems (e.g. with installed machinery, etc)	-
3. Market conditions		
IPC	Intensity of price competition in the product market (five-point Likert scale)	+
INPC	Intensity of non-price competition in the product market (five-point Likert scale)	+
CONC16-50	Three dummy variables for market concentration based on the	?
CONC11-15	number of principal competitors in the world (product) market	?
CONC1-10	(16 to 50, 11 to 15, 1 to 10 competitors; firms with more than 50 competitors as reference group)	?
4. Type of production technique/products		
Product characteristics (dummy variables with ‘standardized products’ as reference group)		
PDMARKET	Product differentiation	-
PDUSER	Products according to user specifications	-
Process characteristics (dummy variables with ‘single-piece production’ as reference group)		
SBATCH	Small-batch production	+
LBATCH	Medium-batch / large-batch production	+
CONTFLOW	Continous flow / mass production	+
5. Absorptive capacity		
HUMCAP	Percentage share of highly qualified employees	+
COOP	Cooperation in R&D activities (dummy variable)	+

6. Firm size		
L, L^2	Number of employees and its square	+/?
7. Control variables		
INT90	Intensity of AMT in 1990 (starting year of the programme)	?
Industry Dummies	Metalworking, machinery, electrical machinery/electronics, chemicals/plastics (with „other industries“ as reference group)	?

TABLE IV
Ordered Probit Estimation of the Adoption Model; Total Sample

Explanatory Variables	DAMTINT (1)		DAMTINT (2)	
Objectives				
FINCOMP	-.15**	(.06)	-.14**	(.06)
COST	.11*	(.06)	.12**	(.05)
FLEX	.22**	(.06)	.23**	(.06)
DEV	.06	(.06)		
QUAL	.09*	(.06)	.09*	(.05)
BEST	.20**	(.06)	.18**	(.06)
Impediments				
TECH	.03	(.06)		
KNOWPERS	.04	(.06)		
RESIST	.00	(.06)		
INVCOST	-.11*	(.06)	-.13**	(.06)
UTILIZ	.05	(.06)		
COMPAT	-.05	(.05)		
Market conditions				
IPC	.09	(.06)		
INPC	-.06	(.06)		
CONC16-50	.10	(.17)		
CONC11-15	.00	(.15)		
CONC01-10	.11	(.14)		
Type of production				
PDMARKET	.07	(.12)		
PDUSER	-.02	(.14)		
SBATCH	.05	(.12)		
LBATCH	.32**	(.12)	.33**	(.11)
CONTFLOW	-.04	(.15)		
Absorptive capacity				
HUMCAP	.00	(.01)		
COOP	.27**	(.12)	.26*	(.12)
Firm size				
L	.34**	(.15)	.32**	(.14)
L^2	-.02*	(.01)	.-02	(.14)
Control variables				
INT90	-.15**	(.02)	-.15**	(.02)
Metalworking	.04	(.16)	.05	(.16)
Machinery/vehicles	.00	(.18)	.10	(.16)
Electr. machinery/electronics	.24	(.19)	.36**	(.17)
Chemicals/plastics	.42*	(.23)	.48**	(.22)
N	463		463	
McFadden R2	.114		.106	
LR statistic (χ^2)	113		104	

% concordance	72.1	71.3
Equal slope test (χ^2)	31	19

Note: Equation (1) contains all model variables as specified in section 5 (see table III); equation (2) contains only the variables with statistically significant coefficients at the 10%-level (restricted model). Standard errors are included in brackets (**, * indicate stati-stical significance at the 5%-level and 10%-level resp.). Intercepts have been throughout omitted.

TABLE V
Probit Estimation of the Policy Equation; Total Sample

Explanatory Variables	CIMTHM (stimulus)	
Firm size		
L	-.15	(.20)
L^2	.03	(.02)
Groups of industries		
Metalworking	.49**	(.23)
Machinery/vehicles	.25	(.23)
Electrical machinery/Electronics	.16	(.24)
Chemicals/plastics	-.32	(.40)
Ownership status		
Affiliate company	-.09	(.17)
Firm in foreign ownership	.37*	(.22)
Financing difficulties	.26*	(.15)
Previous experience with Government support	.29*	(.17)
N	463	
McFadden R2	.060	
LR statistic	21	
% concordance	66.9	

Note: **, * indicate statistical significance at the 5%-level and 10%-level resp.; intercepts have been throughout omitted.

TABLE VI
Simultaneous Probit Estimation of the Adoption and the Policy Equation

Explanatory Variables	DAMTINT	CIMTHM	DAMTINT	CIMTHM
	Total Sample		Reduced Sample[1]	
	(1)	(2)	(3)	(4)
FINCOMP	-.14** (.07)	-	-.14* (.08)	-
COST	.11** (.05)	-	.11 (-07)	-
FLEX	.23** (.06)	-	.27** (.07)	-
QUAL	.10** (.05)	-	.13** (.06)	-
BEST	.19** (.06)	-	.20** (.07)	-
INVCOST	-.12** (.06)	-	-.06 (.07)	-
LBATCH	.33** (.11)	-	.26** (.13)	-
COOP	.25** (.12)	-	.22 (.14)	-
L	.33** (.16)	-.03 (.27)	1.53** (.63)	-1.68 (1.30)
L^2	-.02 (.02)	.01 (.04)	-.42 (.54)	.08 (.17)
INT90	-.15** (.02)	-	-.20** (.03)	-
Firm in foreign ownership	-	.46** (.23)	-	.28 (.34)
Financing problems	-	.13 (.16)	-	.17 (.20)
Previous experience with governmenr support	-	.41** (.17)	-	.51** (.22)
CIMTHM (policy variable)	.08 (.12)	-	.28* (.16)	-
DAMTINT (adoption variable)		- (.13)	.07	- -.09 (.15)
N	463		330	
$Q_T(\Theta: \aleph^2 = 21.1; df=14)$	24.5		15.8	
ρ	.10 (.09)		.21** (.12)	
R	.250	.087	.239	.087

Note: [1] Reduced sample: firms which at the start of the promotion programme in 1990 did not yet apply AMT. Standard errors are included in brackets (**, * indicate statistical significance at the 5%-level and 10%-level resp.). Intercepts and industry dummies have been throughout omitted.

Appendix I

TABLE A1
Description of the Data Set

	N	%
Total manufacturing	463	100
Industry		
Food, beverage	19	4.1
Textiles	14	3.0
Clothing, leather	5	1.1
Wood	10	2.2
Paper	15	3.2
Printing	13	2.8
Chemicals	14	3.0
Pubber, plastics	24	5.2
Glass, stone, clay	16	3.5
Metals	99	21.4
Machinery	84	18.1
Electrical machinery	27	5.8
Electronics, instruments	83	17.9
Vehicles	17	3.7
Other manufacturing	23	5.0
Firm size (number of employees)		
5-49	83	17.9
50-99	87	18.8
100-199	127	27.4
200-499	100	21.6
500 and more	66	14.3

TABLE A2
Factor Analysis With the Objectives of / Motives for the Adoption of AMT

Objectives / motives	*Factor loadings (at least 0.40)*					
	(1)	(2)	(3)	(4)	(5)	(6)
Availability of financial funds	0.80					
Existing equipment already depreciated	0.67					
Favourable macroeconomic prospects	0.67					
Competitors introduce AMT	0.57					
Declining market share	0.53					
Reduction of production time	0.66					
Need of reducing costs in general		0.62				
Labour saving		0.58				
Higher utilization of equipment		0.55				
Securing delivery in time		0.45				
Need to improve the organization of production		0.40				
Higher quality of product development			0.73			
Reduction of time needed to develop new products			0.69			
Introduction of „intelligent products“			0.49		0.49	
Improving information for cost calculations			0.48			
Reduction in space requirements			0.43			
Fundamentally new production concept				0.72		
Higher flexibility of work organisation				0.69		
Higher flexibility within the firm in general				0.43	0.41	
Reduction of inventories				0.42		
Higher product variety					0.79	
Higher product quality				0.43	0.54	
Higher flexibility at the market					0.53	
Adjusting to „best practice“						0.78
Becoming familiar with a new technology						0.62
Securing technological lead						0.41
Statistics						
Number of observations						501
Kaiser's measure of sampling adequacy (MSA)						.860
Variance accounted for by the six components						.546
Root mean square off-diagonal residuals (RMSE)						.060
Variance accounted for by each factor	6.70	2.02	1.67	1.40	1.29	1.12
Final communality estimate						14.2

Characterization of the six factors based on the factor pattern
(1) Favourable financial conditions; high competitive pressure (FINCOMP)
(2) Cost reduction (COST)
(3) Improving product development (DEV)
(4) Higher flexibility (FLEX)
(5) Higher product quality (QUAL)
(6) Securing technical lead / „best practice“(BEST)

TABLE A3
Factor Analysis With the Impediments to the Adoption of AMT

Impediments	*Factor loadings (at least 0.40)*					
	(1)	(2)	(3)	(4)	(5)	(6)
Lack of engineers / technicians	0.72					
Lack of IT specialists	0.67			0.41		
Lack of other qualified personnel	0.66			0.42		
Intra-muros training too expensive	0.64					
Lack of relevant know-how in general	0.61					
Insufficient support by suppliers of AMT	0.58		0.41			
Investment volume too large		0.82				
Pay-back period too long		0.74				
Liquidity constraints		0.63				
Technology / software too expensive			0.61			
Trend price of technology falling		0.42	0.41			
Technology not yet developed far enough			0.71			
Performance of AMT uncertain			0.65			
Software development too expensive			0.61			
Information costs / problems			0.56			
Difficulties with software or interfaces			0.49			
Resistance to new technology within the firm				0.75		
Organizational problems				0.67		
Insufficient attention of the management				0.67		
Concept for the adoption of AMT not well-defined						
Installed equipment (rather) new					0.74	
Utilization of new production capacity uncertain					0.68	
Extra-muros training too expensive	0.42				0.45	
Insufficient compatibility with existing machinery						0.84
Insufficient compatibility with product portfolio						0.76
Insufficient compatibility with organization						0.65
Statistics						
Number of observations						495
Kaiser's measure of sampling adequacy (MSA)						.899
Variance accounted for by the six components						.596
Root mean square off-diagonal residuals (RMSE)						.053
Variance accounted for by each factor	8.26	2.18	1.73	1.47	1.04	1.00
Final communality estimate						15.7

Characterization of the six factors based on the factor pattern
(1) Lack of knowledge / lack of qualified manpower (KNOWPERS)
(2) High investment costs (INVCOST)
(3) High technological costs and uncertainties (TECH)
(4) Intra-firm resistance to new technology (RESIST)
(5) Capacity utilization uncertain (UTILIZ)
(6) Compatibility problems (COMPAT)

Appendix II

Wording of the Policy Question:
(question 6 of the questionnaire)

Have you got *financial or other support by a government agency* for introducing or extending the use of Advanced Manufacturing Technologies (AMT) in your enterprise?

Yes o No o

If yes, how strong has been the *impulse you got from the support* for the introduction or extension of AMT in your firm?

Type of Support						Stimulus very weak 1	2	3	4	very strong 5
- Information/training	no	o	yes	o	→	o	o	o	o	o
- Consulting	no	o	yes	o	→	o	o	o	o	o
- R&D projects	no	o	yes	o	→	o	o	o	o	o

(For a full version of the questionnaire see Arvanitis et al. 1998 or *www.kof.ethz.ch*)