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Arbeitspapiere/ Working Papers

Spyros Arvanitis

Microeconomic Approaches
to the Evaluation of RTD Policies:
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1. Microeconomic Approaches to the Evaluation of RTD Policies: A Non-technical Summary of the State of the Art

Spyros Arvanitis

INTRODUCTION

Starting point of the approach in this chapter is that the various tools of assessment of the effectiveness of technology programmes, both qualitative and quantitative, can be seen as 'complementary and interrelated rather than substitutable and disconnected' (Capron and Van Pottelsberghe, 1997, p. 35). Most methods used in evaluation studies are designed to cover specific aspects and answer specific questions related to a particular step of the evaluation process. Therefore what is really needed, is a conceptual framework for an overall impact assessment of technology programmes indicating which evaluation method is most suitable for which kind of impact.¹ For example, narrowly defined economic effects of a certain policy measure such as the impact on economic performance of a firm can be presumably better grasped by econometric methods. Widely conceptualized organizational or social effects are more suitably covered by qualitative methods and case studies.

In this section we want to give a brief survey of the econometric approach in the evaluation literature and discuss some aspects of it. Particularly, we limit our presentation to studies at the *firm level*; investigations at the meso level (industries, sectors) and the economy as a whole are considered only in connection with the analysis at the firm level. Moreover, we consider primarily methodological questions and do not survey the evaluation results.

Most existing microeconomic evaluation studies refer to policy measures aiming at enhancing the R&D capacity of firms in general or of particular groups of firms characterized by certain attributes such as firm size, industry, type of technology, etc. Policy support takes mostly the form of subsidies to or

fiscal incentives for commercial R&D.² Other policy tools include government and university research supplying the business sector with substantial R&D inputs.³

A second smaller group of microeconomic evaluation studies deals with government programmes supporting the diffusion of new technologies (for example advanced manufacturing technologies) in business sector mostly for some particular firm categories (small enterprises, firms belonging to high-tech industries, etc.).⁴ Both groups of studies have a common conceptual basis and are confronted with the same methodological problems to be outlined in the next section.

In general, the methods to be surveyed here are appropriate when the implications of a public policy are to be scrutinized at the level of participating individual agents (firms, organizations, etc.). Hence, all policy interventions that target firms are possible candidates for microeconomic evaluation, for example programmes that aim to foster R&D activities (tax policy, subsidies, etc.), R&D collaborations among firms, the adoption of new technologies, start-up assistance for new high-tech-firms, etc.

FRAMEWORK OF MICROECONOMETRIC EVALUATIONS

Microeconomic Models in an One-Equation Framework

Evaluating the effects of government-sponsored projects, one has to face the question of what would have taken place without the policy support, which is a rather difficult exercise in counterfactual analysis (Klette et al., 2000, p. 472; Hall and Van Reenen, 2000, p. 458). In order to absolve this exercise satisfactorily one has to deal with a series of problems.

First, given the declared goals of the policy support (for example a better firm performance as a result of R&D subsidies or subsidies for introducing some new fabrication technique) the evaluator needs to know if policy support can influence these firms' outcomes directly (for example existence of a direct relation between firm performance and R&D subsidies) or indirectly through some other economic variable (for example government research is a complement to private R&D, thus enhancing the firm performance via the complement relation to private R&D). Moreover, the evaluator should be able to identify the factors other than policy support determining firm's outcomes Y ; i.e. a *model* should be constructed, explaining for example firm performance, which in addition to the determinants (vector X) of firm performance postulated by economic theory also includes a policy variable P which discriminates supported from non-supported firms.

Second, in many cases *externality problems* with respect to the effects of policy support have to be considered. Usually it is assumed that there are no spillover effects of the government promotion programmes to the non-supported firms. In case that this condition does not hold, the policy effects could be underestimated if the non-supported firms tend to benefit for example from the enhanced R&D activities of the supported firms (positive external effects) or overestimated if the non-supported firms suffer some disadvantage relative to the competitors receiving policy support (negative external effects). A standard procedure to deal with this problem is to introduce variables measuring spillover effects (for example the spatial density of firms in the same industry) in the evaluation model.⁵

Third, since neither the firms receiving support, nor those not applying for government-sponsored projects, can be considered random draws, the construction of a *valid control group* is a challenging task to be performed by the evaluator. 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. Any evaluation procedure will have to take this problem explicitly into account.

Assuming that the goal variable (for example, productivity or adoption of a certain technology) of a firm i in period t denoted $Y_{i,t}$ is determined by a vector of variables $X_{i,t}$ the evaluation procedure may be presented formally by

$$Y_{i,t} = \alpha_i + \beta_1 X_{i,t} + \beta_{2,i} P_i + \text{control variables} + e_{i,t} \quad (0.1)$$

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, α_i is a firm specific intercept representing permanent differences in firm performance, control variables for the sectors or industries the firms belong to and $e_{i,t}$ is a stochastic term. In the above expression the subscript i of the β_2 coefficient indicates that in general the outcome of the programme may not be identical for all participants, thus reflecting heterogeneous responses to policy support among the programme participants differing for example with respect to firm size, industry, etc.

The formulation of equation (0.1) takes it as given that the evaluator disposes of a structural model linking the vector $X_{i,t}$ to $Y_{i,t}$ (for example a productivity model or a model of technology adoption). In case that nothing or

very little is known about X , i.e. the factors determining Y , a non-structural model may be used which takes the following form:

$$Y_{i,t} = \alpha_i + \beta_1 Y_{i,t-1} + \beta_{2,i} P_i + \text{control variables} + e_{i,t} \quad (0.2)$$

In the equations (0.1) and (0.2) the impact of policy promotion is measured directly and can be interpreted straightforwardly based on the signs of $\beta_{2,i}$. 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.⁶ 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.

In addition to such *direct* effects the policy measures may also show *indirect* effects through the influence on some components of the vector of the determinants $X_{i,t}$ in equation (0.1), for example, in the case of a technology adoption model through the reduction of specific barriers to adoption. To take account of such interactions between P_i and $X_{i,t}$ the following modification of equation (0.1) can be considered:

$$Y_{i,t} = \alpha_i + \beta_{1,1} X_{i,t} \text{ (if } P > 0) + \beta_{1,2} X_{i,t} \text{ (if } P = 0) + \text{control variables} + e_{i,t} \quad (0.3)$$

In this case we split the effect of X in two components: one for the firms receiving policy support ($P > 0$; coefficient $\beta_{1,1}$) and one for non-supported firms ($P = 0$; coefficient $\beta_{1,2}$). For a certain x_i (element of vector X in (0.3)) with a negative impact on the goal variable (for example financial barriers for rapid technology adoption) $\beta_{1,1} < \beta_{1,2}$ in absolute terms would point to a favourable indirect effect of policy support reducing in the above mentioned example the negative impact of financial barriers.

Most evaluation studies on this line, especially those dealing with policy support of R&D activities and also disposing of *panel data* or *repeated cross-section data* on participants and non-participants, use the *one-equation framework* presented by equation (0.1). Intercept α_i , as already mentioned, is treated as a firm-specific parameter, thus being allowed to be correlated with P_i . In this way, the estimated $\beta_{2,i}$ -parameter is not biased even if the supported firms are non-randomly selected. Under these conditions, one main estimation procedure is proposed in the econometric literature: the so-called ‘difference-in-differences’ estimator built on the differences between supported and unsupported firms with respect to the change (difference between t_0 and t_1) of

the goal variable from before (t_0) to after (t_1) the policy support (see the chapter of Keilbach in this volume for more details).

In a series of recent papers referring to the manufacturing extension programmes in the USA (programmes promoting the adoption of modern production technologies and business practices in smaller firms) the effects of manufacturing extension on the productivity dynamics of client plants were investigated (Jarmin, 1998, 1999). In these studies fixed-effect (difference) estimators (one-equation framework) were used to obtain estimates of the programme impact which were free of selection bias. A similar approach has been applied also in some earlier USA studies on manufacturing extension on client performance (see for example Oldsman, 1996; for a review of this literature see Shapira et al., 1996).

Microeconometric Models in a Two-Equation Framework

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 (0.1) above and a selection equation. Based on assumptions on the joint distribution of the residuals of these two equations, the coefficient β_2 in (0.1) can be estimated by a simultaneous or a sequential approach.

Some studies build a *two-equation framework* by adding to the basic evaluation equation (0.1) a second equation explaining the policy variable P_i . Particularly, we consider here two evaluations of programmes promoting the diffusion of advanced manufacturing technologies (AMT) in manufacturing firms in Switzerland and Austria in the nineties which were recently conducted on ground of a common philosophy (see Arvanitis et al., 2002 and Geier et al., 2000).⁷ In this approach two equations were estimated simultaneously, one for technology adoption A (goal variable) and a second one for government support P (policy equation):

$$A_i = \alpha_i + \beta_1 X_i + \beta_{2,i} P_i + \text{control variables} + e_{i,t} \quad (0.4)$$

$$P_i = \gamma_i + \gamma_1 Z_i + A_i + u_i \quad (0.5)$$

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 in the government programmes. Further, it is reasonable to assume that firms with prior experience in the technology promoted by policy measures could be more eager to participate in 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 (Armingier et al., 1996).

A particular advantage of this approach is that important features of the political economy of firm participation in government programmes can be explicitly taken into consideration in the evaluation procedure. However, there is no standard theory explaining under which conditions a firm would obtain government support. This is 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 (for example 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 type of technology which is promoted by a certain programme.

In the above-mentioned evaluation studies of AMT programmes a series of possible factors determining the probability of a firm participating in a government programme were tested in the framework of a probit model in order to obtain a valid policy equation for the two-equation evaluation procedure.

First, measures of innovation intensity (input- and output-oriented innovation indicators) and measures for the use of external knowledge sources and the participation to R&D joint projects with other firms were inserted in the policy equation reflecting a firm’s capacity to claim successfully policy support as well as to absorb and exploit new knowledge.

Other variables included in the policy equation were a productivity measure taking account of the argument that firms which perform well also exhibit above-average capabilities for getting public financial support, and a measure of export orientation as an additional indicator for advantages in information-search activities.

Third, some more policy-related variables such as proxies for firms’ experience with other government programmes with similar goals and measures of financial barriers to investing and innovating were also considered.

Finally, the age of the firm, the ownership structure (foreign vs. domestic; parent vs. affiliate vs. independent firm), the firm size and industry dummies were included as control variables in order to capture further unspecified effects.

The empirical analysis showed that for example in the Swiss case besides firm size and type of industry a firm is operating in, the relevant factors explaining the participation decision of the single firm included ownership status, financing difficulties and previous experience with government support in earlier programmes. In the Austrian case important factors besides owner status and type of industry were firm age, wage level, capital intensity and R&D intensity.

Matching Methods

Recently, matching methods based on direct comparisons of participating and non-participating agents, which were first used in labour market evaluations,⁸ were also applied in the evaluation of technology programmes (for example Geier et al., 2000, Almus and Czarnitzki, 2001, Czarnitzki and Fier, 2002).

A comparison of participants and non-participants based for example on a vector X of factors determining the outcome Y in equation (0.1) which may also influence the participation decision (selection bias) is only possible when the “conditional independence assumption” holds. This assumption states that, once the evaluator conditions on X , participation in the programme is independent of the outcome in the non-participation state. It requires that all variables that affect both participation and outcomes be included in the matching. Certainly, it is not possible to thoroughly fulfil such a requirement in real-life evaluation, but the awareness of this rigorous condition may force evaluators to more careful thinking, guided by economic theory, about what variables do and do not affect participation and outcomes. Clearly, making this assumption plausible in practice requires the availability of rich data.

More recent matching methods (“propensity score” matching) compare participants and non-participants based on the estimated probability of participation $P(X)$ rather than on a vector of observed characteristics X . The participation probability $P(X)$ can be estimated with a standard probit or logit model. The advantage of matching on $P(X)$ rather than X is that in the first case the search for close matches concerns only the scalar $P(X)$, while in the latter close matches for every single element of vector X are needed, which is a rather too rigorous data requirement. Based on the “propensity scores” estimates a close match can be found through a “nearest-neighbour” matching method (Heckman et al., 1999, p. 1953). In this method the non-participant closest (in terms of a minimum distance measure with respect to $P(X)$) to each participant is chosen as the participant’s match. The outcome of the “nearest neighbour” approximates the participant’s counterfactual non-participation outcome.

A major advantage of the matching methods versus the regression approach is that matching is non-parametric. As such, it avoids the functional form restrictions implicit in running a regression of some kind. Evidence from studies which compare directly matching and regression estimates suggests that avoiding these functional form restrictions can be important to reducing bias. Thus, it looks reasonable to apply both regression and matching methods using the same vector X of explaining factors in a given evaluation project (for example see Geier et al., 2000 for such an evaluation study).

ADVANTAGES AND LIMITATIONS OF ECONOMETRIC APPROACHES

A first advantage of econometric approaches relative to alternative methods is that the evaluation analysis is based on the explicit formulation of theory-based causal relationships between the goal variables of a policy support programme and the factors influencing these goal variables. Second, factors related to the political economy of the selection (or participation) of firms with respect to the support programme in question are explicitly taken into consideration in the evaluation procedure.

Of course there are (technical) limits of the validity of econometric methods of evaluation, which are to be taken into consideration when designing an evaluation study; such econometric matters are extensively discussed for example in Heckman et al. (1998). The most serious shortcomings of the use of econometric methods in policy evaluation are often 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. The problems related to correctly specifying the empirical model and jointly testing the assumed causal relationships - to be confronted with in practically every econometric study - are the main sources of difficulties.

Further problems may arise if good economic theory is lacking in the fields covered by an evaluation on which the empirical models should be based.

Keeping the definition of the goal variable rather *narrow*⁹ (for example evaluation of the narrow *intermediate* goal of public support of an AMT promotion programme, that is a more rapid and broader diffusion of AMT compared to non-participating firms, instead of the rather broad *final* goal of the programme of enhancing the performance of the participating firms, for example in terms of productivity, etc.) would sometimes help to tackle such problems. Taking broader goals into consideration would often involve a two- or three-stage modelling and/or the explicit consideration of externalities.¹⁰

In some cases a more complicated model may be used in order to call attention to the chain of events leading from policy intervention (launching of a support programme) to desired policy outcomes; this could allow the separate evaluation of intermediate goals. Oldsman (1996) offers a good example of such an approach. Mostly, the provided support services are intended to lead to specific actions or changes in behaviour within the firm (goal variable: "action", for example "change of plant layout" or "adoption of total quality management"). Actions taken by the firm are intended to resolve identified problems, resulting in improvements along a number of dimensions (goal variable: "intermediate impacts", for example manufacturing lead time reduction). By resolving problems, it is expected that the firm will increase

sales, reduce costs, or otherwise generate higher profits (goal variable: “business outcomes”). Finally, these favourable business outcomes are expected to lead to desired policy outcomes, for example increased employment (goal variable: “policy outcomes”). If data are available for each stage of this process, an econometric evaluation of each of these stages could be tractable; this could help to better illuminate several dimensions of the evaluation process which may be crucial for the success of the policy programme involved.

A further practical problem for the evaluator refers to the effort needed in order to persuade a large number of participants and non-participants to disclose sensitive firm data. The collection of such data in combination with a national or European survey (for example CIS survey) conducted by well-known and trustworthy institutions could help to reduce this type of difficulties.

To sum up, following conditions should be fulfilled in order to be able to apply satisfactorily the econometric methodology:

1. The implications of the applied policy measures are scrutinized at the level of participating individual agents (firms, organizations, etc.).
2. The goals of the support programme can be formulated in such a way, that their degree of attainment can be measured by some indicator or a set of indicators, at best with indicators which are already well-known and therefore widely accepted.
3. The relationship between the policy goals and the used policy instruments can be modelled based on some piece(s) of available economic theory.
4. Data for a large number of firms are available or is planned to be collected specifically for the evaluation study.
5. Data are needed not only for programme participants, but also for non-participants.

CONCLUDING REMARKS

In general, part of a good evaluation strategy should be the parallel use of several evaluation methods in order to check up the results and correct for the shortcomings of the single methods. For example, properly designed case studies based on a number of “representative” firms (for example supported vs. non-supported; large vs. small; belonging to a hightech sector vs. belonging to a traditional sector, etc.) could be used not only to control for the plausibility of the results of the econometric analysis but also to help focus the really relevant factors in the evaluation equations. The analysis of subjective assessments of the firms of the impact of a policy measure can also be utilized to check the consistency and plausibility of econometric analysis.¹¹ Of course

there is also a price to pay for such a multi-dimensional strategy, which is the high cost of conducting evaluation work along several lines.

In spite of the shortcomings of the microeconomic 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.

NOTES:

- 1 See Georghiou and Roessner (2000) for a recent critical survey on evaluation methodologies; see also the Special Issue of the 'IPTS Report' of December 1999 on the evaluation of RT programmes of the European Union. In OECD (ed.) (1997) are reported the results of an international conference on techniques of technology evaluation reflecting the state of the art in this field.
- 2 Klette et al. (2000) give a comprehensive survey of the empirical studies dealing with R&D subsidies including an excellent presentation of the methodological problems related to such microeconomic investigations. Hall and Van Reenen (2000) review in a recent article the empirical evidence on the effectiveness of fiscal incentives for R&D and also discuss methodology.
- 3 See Guellec and Van Pottelsberghe (2000) for a comparative study of the impact of R&D subsidies as well as of government and university research on business sector R&D activities at country level; this study includes also a brief but quite comprehensive discussion of a series of methodological problems.
- 4 Arvanitis and Hollenstein (1997) and Jarmin and Jensen (1997) describe microeconomic approaches for evaluating programmes aiming at the diffusion of new manufacturing technologies in Switzerland and the USA respectively.
- 5 See Griliches (1979) for the concept and measurement of R&D spillovers, Branstetter and Sakakibara (1998) for an evaluation study which explicitly takes account of spillover effects; see Klette et al. (2000), p. 481f. for the econometric problems related to spillover effects.
- 6 The argument runs the other way around if a policy measure aims at decreasing Y.
- 7 See also for example Busom (2000) for a recent study on R&D subsidies using a two-equation framework.
- 8 See Heckman et al. (1997) as a main reference and Smith (2000) for a critical non-technical survey of these methods.
- 9 This means in many cases persuading the policy makers to keep the goal narrow, hence operationable in terms of policy evaluation, which is often a very difficult task.
- 10 For example, to avoid externality problems an evaluator may choose a higher level of aggregation for his/her analysis. At the industry or country level such external effects are to a large extent internalized.

- 11 See for example Sakakibara (1997) and Arvanitis et al. (1998), ch. 3 for recent examples of the use of firms' assessments of policy impact to supplement the econometric analysis. Both studies found that the firms' responses were consistent with their econometric findings.

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