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The Matching methodology in agricultural economics: applications from Austria

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Abstract

The Matching methodology is increasingly applied in agricultural economics in order to estimate unbiased effects in expost analysis of, for example, governmental support or agricultural decision-making. Matching relies on the assumption of conditional independence and controls for selection bias by balancing observable covariates, which requires the identification of all disturbing variables. This thesis applies and discusses the applicability of the Matching methodology in agricultural economics for different research questions. To do so, different models are introduced which are based on the Matching method. Some of them include a non-parametric difference-in-difference estimator, which allows for the controlling of unobservable influences. Using different data sets, we analyse the effects of government-supported farm investments and a low-input decision in dairy farming with regard to structural and economic outcomes. The results indicate that there are only small effects on farm income in both case studies. Whereas supported farm investment leads on average to a continuous enlargement of production, a low-input decision in dairy farming leads to a decrease within these parameters. It can also be shown that farm investments lead to an intensification in husbandry farming, but that both decisions show a positive influence on the adoption of organic farming. We can conclude that, due to data shortage on the selection processes, the application of the Matching methodology in agricultural economics is still challenging; however this thesis shows that the applied Matching models lead to plausible results, and the great influence of certain variables on the selection processes on farms. The inclusion of other research designs and methods can help to improve the accuracy of the estimation results in the future.

Kurzfassung

Die Matching Methode wird, unter anderem durch ihren semiparametrischen Charakter, immer häufiger in der agrarökonomischen Forschung angewendet. Aufbauend auf die Annahme der bedingten Unabhängigkeit kontrolliert diese für beobachtbare Einflüsse und ermöglicht dadurch die Ermittlung von fehlerfreien Effekten in ex-post Analysen. Das Ziel dieser Arbeit ist die Anwendung und Diskussion dieser Methode in verschiedenen agrarökonomischen Fragestellungen. Dazu werden Modelle erstellt, die sowohl die Matching Methode, als auch eine Kombination mit dem Differenz-in-Differenz Schätzer beinhalten. Letzteres erlaubt die Kontrolle von nicht beobachtbaren Einflüssen. Unter Verwendung verschiedener Datensätze werden damit die Effekte einer Investitionsförderung und einer Low-input Produktion auf Milchviehbetrieben in Österreich hinsichtlich struktureller und ökonomischer Variablen analysiert. Die Ergebnisse zeigen, dass beide Entscheidungen einen geringen Effekt auf das landwirtschaftliche Einkommen der jeweiligen Betriebe haben. Die Investitionsförderung führt zu einer kontinuierlichen Erweiterung der Produktion und zu einer Intensivierung in der Tierhaltung auf den jeweiligen Betrieben. Eine Low-input Entscheidung auf Milchviehbetrieben hat hingegen eine negative Auswirkung auf das Wachstum dieser Betriebe. Beide Entscheidungen haben einen positiven Einfluss auf den Einstieg in den biologischen Landbau. Hinsichtlich der Anwendung der Modelle kann gezeigt werden, dass die Anwendung der Matching Methode durch den Mangel an Daten über derartige Entscheidungsfindung am landwirtschaftlichen Betrieb begrenzt ist. Dennoch führt die Anwendung der Modelle zu plausiblen Ergebnissen und stellt die Einflussnahme einzelner beobachtbarer Variablen auf die jeweiligen Selektionsprozesse dar. Um die Aussagekraft derartiger Modelle zu erhöhen, sollten auch in Zukunft andere Methoden in einem solchen Forschungsrahmen mitaufgenommen werden.

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Kirchweger, S., Kantelhardt, J., 2015. The dynamic effects of government-supported farm-investment activities on structural change in Austrian agriculture. *Land Use Policy 48, 73-93. (Impact Factor 2014: 2.631)* 39

Kirchweger, S., Eder, M., Kantelhardt, J., 2014. Economic impacts of strategy selection in Austrian dairy farming: an empirical assessment. *Proceedings of the 11th European IFSA Symposium 1- 4 April 2014 in Berlin, Germany 8.* 61

Moser, T., Kapfer, M., Sandbichler, M., Kirchweger, S., Kantelhardt, J., 2015. Effect of investment activities and investment support on economic parameters of dairy farms in Austria. *Berichte uber Landwirtschaft 93. (Impact Factor 2014: 0.310)* 69

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Part I: Framework Article

1 Introduction

The Matching methodology was originally introduced in the works of Rubin (1977) and Rubin and Rosenbaum (1983). Since then, the application of this methodology has become well established, especially in the research fields of medicine, labour-market analysis and economics (Caliendo and Kopeinig, 2008). In the field of agricultural economics, applications have increased very recently, where programme evaluation (Datta, 2015; Michalek, 2012; Pufahl and Weiss, 2009; Smets et al., 2013), strategic decision-making (Mayen et al., 2010; Schilling et al., 2014a; Schilling et al., 2014b), the evaluation of innovation and new marketing strategies (Bosch and Zeller, 2013; Shete and Rutten, 2015; Takahashi and Barrett, 2014; Villano et al., 2015; Wainaina et al., 2014; Willy et al., 2014) are analysed. This increasing popularity in agricultural economics might be due to the fact that it is performed in a non/semi-parametric way and therefore has the considerable advantage of requiring fewer functional forms than regression-based analyses (Imbens and Wooldridge, 2009; Lechner, 2002b; Smith and Todd, 2005). Further advantages of Matching are its allowance for arbitrary heterogeneity of the effects, its simplicity and its intuitive appeal (Lechner, 2002a, b).

However, this methodology relies on the strong assumption of conditional independence (selection on observables), which requires that the variables potentially influencing the investigated treatment selection[1] and outcome variables, and therefore generating biased effects, are observable. Independence of treatment and the outcome variable, which is necessary to estimate unbiased effects, can then be established when these variables are controlled or, in the case of Matching, balanced between the group of farms making a decision and the group not making this decision. The selection of these variables is the most important task in the Matching procedure. It is referred to as "a knife-edge decision", as too many, too few or inaccurate covariates can violate the mentioned assumption (Blundell et al., 2005; Ho et al., 2007; Rosenbaum, 2010). Therefore the applicability of the Matching methodology is highly dependent on the availability of rich data.

The main objective of this thesis is to discuss the applicability of the Matching methodology in agricultural economic research questions and available data sets. To do so, several models are presented which apply the Matching methodology (Kirchweger et al., 2014) as well as in combination with the difference-in-difference estimator (Kirchweger and Kantelhardt, 2015; Kirchweger et al., 2015). The later models not only control for observable but also for unobservable influences. Both methodologies are explained in detail in Chapter 2. The models are based on different data sets, such as the Austrian voluntary bookkeeping data and integrated administration and control system (IACS) data. Furthermore,

[1] The term treatment is used because the Matching literature is closely related to medical applications and programme evaluation where certain treatments on people, companies, farms or other units are analysed. Within other applications, as well as in this thesis, the 'treatment' can be a farmer's decision-making.

these models are applied in order to analyse different topics relevant to agricultural economics in Austria. On the one hand, this thesis focuses on the estimation of effects from farm-investment support (Kirchweger and Kantelhardt, 2015; Kirchweger et al., 2015), which plays a major role in Austrian agriculture. This is due to the high share of animal husbandry where investments in buildings and machinery are necessary in order to remain competitive. On the other hand, the models analyse the effects of a low-input strategy decision in Austrian dairy farming (Kirchweger et al., 2014), whose increase becomes, in the context of increasingly volatile in- and output prices, more and more competitive in dairy farming.

For both topics, it is of particular interest to know not only the effects on the competitiveness of the farm but also those effects which are related to changing production intensities or participation in the organic-farming programme (Margarian, 2012). The latter effects concern not only the farm but also the landscape and the environment and therefore society in general. Furthermore, knowledge about the durability and heterogeneity of the effects is of great importance (Pufahl and Weiss, 2009; Tjernström et al., 2013). The model in this thesis, therefore, aims to analyse those estimated effects which concern farm economics and societally relevant parameters, as well as different farm types and durations. The models – as well as their outcome parameters – are displayed in Chapters 3 and 4. A comparative discussion of the estimates results is given in Chapter 5, where the models are then discussed with regard to their applicability in agricultural economics. This chapter also provides an outlook for further research which needs to be done within this context.

2 Applied Methodology

In order to estimate quantitatively the causal effects for a certain outcome variable, it is necessary to compare the outcome of one treated unit with the outcome of the same unit untreated (Brady, 2008; Morgan and Winship, 2010; Speed, 1990)[2]. However, this obviously creates a problem, as one of these situations cannot be observed and is therefore counterfactual. To establish this counterfactual situation of the situation without the treatment, we can use outcomes from observed untreated units. In order to do so, we have to ensure that the compared units are similar, except for the treatment (Rosenbaum, 2005) or, in other words, the independence of the treatment and the outcome variable (Brady, 2008).

The best design to ensure this independence is a randomised experiment. In a randomised experiment, treatment is forced by design to be independent of the potential outcome (Morgan and Winship, 2010). However, so far the use of experimental designs in agricultural economics is considered costly or unethical (Henning and Michalek, 2008). Furthermore, these designs are criticised because participants in the experiment may act differently in the experiments than they do in reality and experiments therefore lack external validity (Maart-Noelck and Musshoff, 2013; Mußhoff et al., 2011). Applications of

[2] This relies on the framework of the potential outcome model, also called the counterfactual model, the Neyman-Rubin model, Neyman-Rubin-Holland model or the Roy-Rubin model

experimental designs in agricultural economics have been done only quite recently and further research might help to overcome the mentioned problems.

Therefore, using observable real world data seems to be more appropriate. However, such observational studies also differ from experiments, as the researcher cannot control the assignment of treatment of individuals (Morgan and Winship, 2010; Rosenbaum, 2005, 2010). Units chose the treatment voluntarily, which might lead to the fact that treated units systemically differ from untreated units which have influences on outcome variables. In other words, through this non-randomised selection, a mutual dependence of the treatment selection (T) and the outcome variable (Y) on one or more variables (X) occurs (see Figure 1).

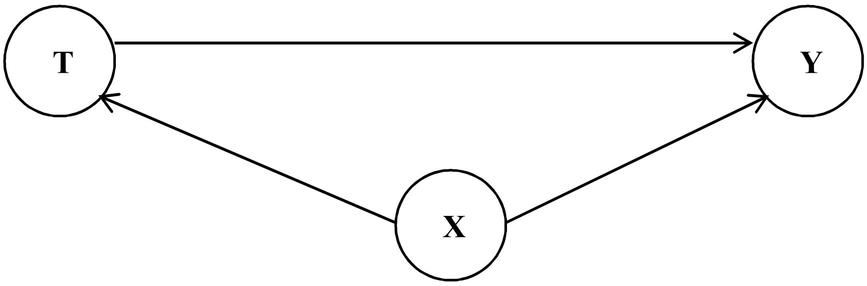

Figure 1: A causal diagram in which the effect of T on Y is disturbed through the so-called "back-door path", a mutual dependence on X. (Source: Morgan and Winship (2010))

When the groups of treated and untreated units are then naïvely compared with each other, this mutual dependence splits the estimated treatment effect into two components: first of all, in the true effect of T causes Y and secondly in the selection bias. However, a carefully investigated treatment-selection process and suitable econometric methods can ensure the independence of the treatment and the outcome.

In this thesis, the average treatment effect on the treated ($\tau \mid (T = 1)$), which is most commonly used in policy programme-evaluation analysis, is applied. This parameter focuses directly on the effects of the treated ($T=1$) and is defined as

$$\tau \mid (T = 1) \; = \; (Y_A^1 - Y_A^0 \mid T = 1) \qquad (1)$$

where Y_A^1 is the outcome of a treated unit and Y_i^0 the hypothetical outcome of the same unit untreated. This means that the estimates only reflect the effect of the treatment for treated units and not for the treatment in general, nor for the possible effects of untreated units.

2.1 Matching

The Matching method is based on the work of Rubin (1977) and Rubin and Rosenbaum (1983) and follows the "conditional independence assumption", also referred to as "the selection on observables assumption", in order to estimate unbiased causal effects. There it is assumed that, under a given vector of observable covariates (X), the outcome (Y) of one individual is independent of treatment (T):

$$Y0, Y1 \perp\!\!\!\perp T \mid X \qquad (2)$$

where ⫫ denotes independence. In other words, through controlling for a vector of covariates $X(x_1, x_2, x_3,...x_k)$, the correlation (R_{ue}) between the error term of the treatment (u) and the error term of the outcome (e) and therefore the selection bias can be dissolved (see Figure 2).

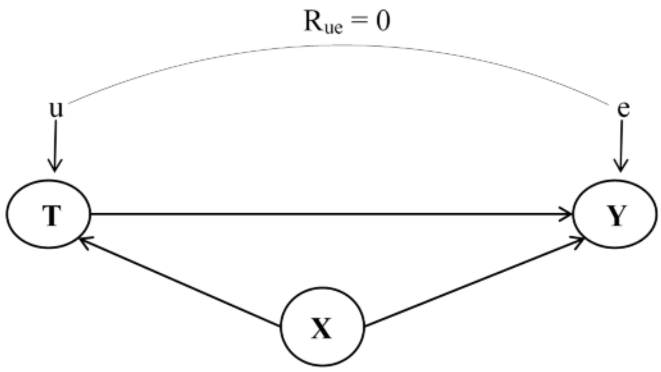

Figure 2: Identification of causal effects through conditioning on an vector of observed variables X (Source: Gangl (2006) adjusted by the author)

It can then be argued that the hypothetical and counterfactual outcome of treated units which do not receive the treatment is the same as the outcome of a control being similar in X. Therefore it can be expressed as

$$E[Y_A^0 \mid X, T = 1] = E[Y_B^0 \mid X, T = 0] \quad (3)$$

where Y_A^0 is the hypothetical outcome for a treated unit but without the treatment and Y_B^0 the expected outcome for a control with similar X.

Matching controls X by pairing treated farms (making the decision) and control farms (not making the decision) with similar X. As mentioned earlier, the selection of X is crucial, as Matching relies on the assumption of conditional independence. This requires the identification of all those variables (covariates) which influence the outcome and the probability of receiving treatment but are not influenced by the decision itself (Rosenbaum, 2010). Guidance can be gained from a statistical, economic and also practical background in order to choose the appropriate covariates. The influence of the decision taken on the covariates can be avoided by using pre-decision covariates. Another major assumption which needs to be applied is the so-called common support assumption. Basically, this requires the existence of controls having similar X as the treated. Both assumptions together are referred to in literature as "strong ignorability", allowing an estimate of the effects for all values of X (Rosenbaum and Rubin, 1983). These reasonably strong assumptions are relaxed through applying the average treatment effect on the treated, where only the outcome of controls must be independent of the treatment and the common support assumption is weaker than for average treatment effects (Caliendo and Kopeinig, 2008).

If these assumptions can be applied, pairing is either done by the selected covariates or estimated balancing scores, such as the propensity score. The first approach uses absolute values of the covariates and is referred to as "Direct Covariates Matching" (DCM). However, the most common approach is

"Propensity Score Matching" (PSM), where the propensity score is defined as the probability of participation (Pr(T=1)) for one individual, given the observed covariates X, independent of observed participation: $p(X) = Pr(T_i=1 \mid x_1, x_2, x_3, \ldots x_k)$. Rosenbaum and Rubin (1983) prove that Matching on the propensity score is sufficient. The estimation of the propensity score is commonly based on the fitted values of a binary logit or probit model, using observed treatment assignment (yes/no) as the dependent and X as the independent variable. PSM differs from DCM, since the values of covariates are usually different within the pairs with the same propensity score but are balanced between the treated and control group (Rosenbaum, 2010).

These two approaches can be expressed with the following formulae, where Formula 1 represents the DCM and Formula 2 the PSM approach:

$$\tau \mid (T = 1) = \sum_{A=1}^{n} Y_A^1 \mid X/n_A - \sum_{B=1}^{n} Y_B^0 \mid X/n_B \quad (4)$$

$$\tau \mid (T = 1) = \sum_{A=1}^{n} Y_A^1 \mid p(X)/n_A - \sum_{B=1}^{n} Y_B^0 \mid p(X)/n_B \quad (5)$$

where the average treatment effect on the treated ($\tau \mid (T = 1)$) is estimated. Y_A^1 is the outcome for a treated unit, X is a vector of observed covariates, n_A the number of treated units, Y_B^0 the outcome of a control unit and n_B the number of controls.

Whereas the propensity score Matching approach has the advantage of reducing the dimension of the Matching covariates, the advantage of the DCM is that it does not require a parametric description of the interrelations between investment support and outcome variables. Accordingly, an exact balance of covariates with little inefficiency is possible and a difference in means is sufficient for the impact analysis (Ho et al., 2007). This characteristic has led Sekhon (2009) to describe the DCM approach as the most straightforward Matching approach. A further, very important advantage of the DCM approach is that it allows a simple stratification of the effects regarding farm groups.

In order to identify pairs, a variety of Matching algorithms is available, including Nearest-neighbour Matching, Calliper Matching, Radius Matching, Stratification Matching, Interval Matching, Kernel Matching and Local Linear Matching[3]. Literature gives almost no advice on the superiority of any one of these algorithms over another. The selection of the appropriate algorithm should rather be done individually, depending on the structure of data (Zhao, 2004). Only Caliendo and Kopeinig (2008), as well as Morgan and Winship (2010), describe better performances of Matching algorithms 'with replacement', where untreated units can serve more than once as controls.

Matching can then be considered successful when the mean of the covariates between treated and control group is balanced. Balance can be judged by conventional testing; alternatively, Ho et al. (2007) recommend using QQ-plots, which plot the quantiles of a variable of the treatment group against that of the control group in a square plot (Ho et al., 2007).

[3] See Caliendo and Kopeinig (2008) for detailed descriptions of Matching algorithms.

2.2 Conditional difference-in-difference estimator

In order to control for possible unobserved bias, the Matching method is often combined with the difference-in-difference estimator (Bergemann et al., 2009; Bernini and Pellegrini, 2011; Gilligan and Hoddinott, 2007; Harris and Trainor, 2005; Heckman and Smith, 1999; Medonos et al., 2012; Michalek, 2012; Pufahl and Weiss, 2009; Smith and Todd, 2005). This procedure is referred to in literature as "conditional difference-in-difference estimator" and can be applied in a semi-parametric setting (Abadie, 2005). The combination allows an estimation of the average treatment effect on the treated by computing the difference of the average development of the treated and matched controls from a specified time before treatment (t') to a specified time after treatment (t'').

The Matching procedure ensures that the group of treated and controls are similar in a vector of observable variables (X). By implementing the factor time and a before- and after-estimation in the analyses, this approach allows control for unobservable bias from permanent differences, as well as from time trends such as price fluctuations (Imbens and Wooldridge, 2009). Therefore, we can extend Figure 2 with permanent differences and time trends influencing the outcome variable (Figure 3).

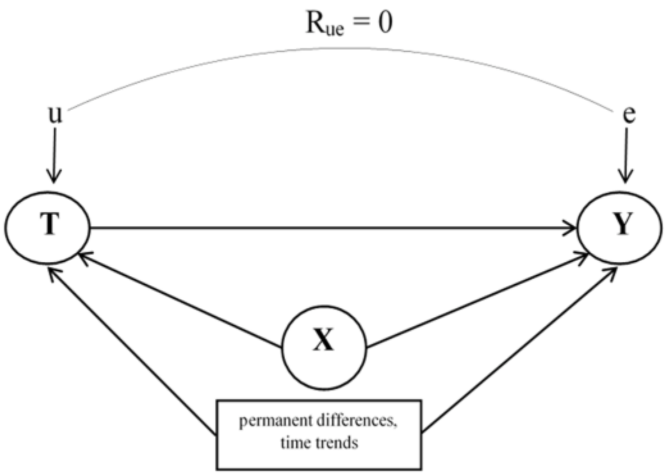

Figure 3: Identification of causal effects through conditioning on observed variables $X(x_1,x_2..x_n)$ and unobserved permanent differences and time trends. (Source: Gangl (2006) adjusted by the author)

It can be assumed that, conditional on these covariates, the average outcomes for treated and controls would have followed similar path in the absence of the treatment (Abadie, 2005). This can be written as

$$E[(Y^0_{A,t''} - Y^0_{A,t'}) \mid X, T = 1] = E[(Y^0_{B,,t''} - Y^0_{B,t'}) \mid X, T = 0] \tag{6}$$

where $Y^0_{A,t''}$ is the hypothetical outcome for a treated unit without a treatment at time t'', $Y^0_{A,t'}$ is the expected outcome for the same unit at time t', $Y^0_{B,t''}$ is the expected outcome for a control unit at time t'', $Y^0_{B,t'}$ the expected outcome for the same unit at time t'. Both units are similar with regard to X at time t'. The estimation of the average treatment effect on the treated($\tau \mid (T=1)$) can then be expressed through the following formulae, where Formula 1 includes the DCM and Formula 2 the PSM approach:

$$\tau \mid (T = 1) = \sum_{A=1}^{n}(Y^1_{A,t''} - Y^0_{A,t'}) \mid X/n_A - \sum_{B=1}^{n}(Y^0_{B,t''} - Y^0_{B,t'}) \mid X/n_B \tag{7}$$

$$\tau \mid (T = 1) = \sum_{A=1}^{n}(Y^1_{A,t''} - Y^0_{A,t'}) \mid p(X)/n_A - \sum_{B=1}^{n}(Y^0_{B,t''} - Y^0_{B,t'}) \mid p(X)/n_B \quad (8)$$

where $Y^1_{A,t'}$ is the outcome for a treated unit after the treatment and $Y^0_{A,t''}$ before the treatment and n_A the number of treated units (A). The second term expresses the same, but for controls (B).

3 Modelling the effects of farm-investment support

Since a non-adequate endowment with investments often restricts agricultural production, investment decisions in agriculture are of high importance. The importance of investments has increased, especially in recent decades, as the availability of possible technology grows (e.g. automatic milking system, irrigation). Correspondingly, farms in Austria increased their expenses for investments in assets by about 75 % from the years 2003 to 2013 (BMLFUW, 2014). It is shown that the majority of these investments in Austria are buildings which are mainly used for dairy farming (BMLFUW, 2014; Dantler et al., 2010; Sandbichler et al., 2013)[4].

Farmers often pursue a variety of goals with an investment decision. Sandbichler et al. (2013) find that investments are often used to increase farm income but also to reduce the workload and work intensity. Therefore, they basically aim to increase their output and/or decrease their inputs, especially labour input, in order to increase productivity (Henningsen et al., 2014). These goals lead to changes in farm structure and intensity which might have an impact on the resources used in the production and therefore on the societal goals of agriculture (Maart-Noelck and Musshoff, 2013; Musshoff and Hirschauer, 2008; Mußhoff et al., 2011). Therefore, an investment decision is not only important for the farm itself but also for the economy and society as a whole.

In order to support farmers in maintaining their farm income, as well as fulfilling the societal expectations of agriculture, governmental programmes have been set up in the European Union to foster such investment activities. The "Modernisation of Agricultural Holdings", a farm-investment support programme, is part of the second pillar of the Rural Development (RD) programme and was, with 11.5% of total funding, the second-most important in the period 2007-14 (EC 2011). Major goals in the programme are to improve the economic performance of farm holdings, enhance technologies and promote innovations. Furthermore, the programme also highlights the presence of the external effects of agricultural investments by formulating such public welfare goals as the promotion of organic production and the improvement of the environmental and animal-welfare status of the farms (EC, 2005). In Austria about €913 million and 6% of its expenditures for RD during 2000-13 were spent within the 'Modernisation of Agricultural Holdings' programme (BMLFUW, 2014). These expenditures

[4] These sources actually analyse investments, which are supported through the European Rural Development (RD). However, in Austria almost every investment is supported within this measure, and therefore these results should display the general investment behaviour of Austrian farms. Only investments in machinery might be underestimated in these sources, as not every piece of machinery is supported.

increased especially in the last RD programme period (2007-13), where about €600 million (two-thirds of the total amount) were spent.

3.1 Effects on economic performance (Model 1 and 2)

In order to estimate the effects of a supported investment decision[5] on the economic performance of investing farms, two similar models are applied (Kirchweger et al., 2015). In both, a conditional difference-in-difference estimator is applied and data from voluntary bookkeeping farms in Austria is used. The models differ in the Matching approach, where in Model 1 Matching is based on the DCM approach (Formula 7) and Model 2 uses PSM (Formula 8). Furthermore, both models control for permanent differences of treated and controls, as well as for time trends like price fluctuations, by applying the difference-in-difference estimator.

To model the effects of a supported investment decision on the economic performance of investing farms, both models use the investment decision as a treatment dummy variable (T). By only considering farms receiving more than €5,000 of investment support, the focus is placed on rather large investments. In order to measure the economic performance (Y), we use the utilised agricultural area (UAA), the share of rented land, total livestock units (LU) and farm output indicating farm growth. Nevertheless, we look at farm/non-farm income and family labour input, as well as share of net worth in total assets, in order to analyse the economic profitability and stability of farms. Differences occur in the vector of covariates (X) which includes variables influencing the investment decision as well as the economic performance of the farm. Within the DCM model, we consider the farm type, the region, part-time farming, age, depreciation and total output. The application of the PSM model allows the use of more covariates. Therefore we add the pre-treatment values for the following variables: utilised agricultural area, share of rented land, total labour input, livestock density, share of net worth on total assets, and non-farm income (see Figure 4).

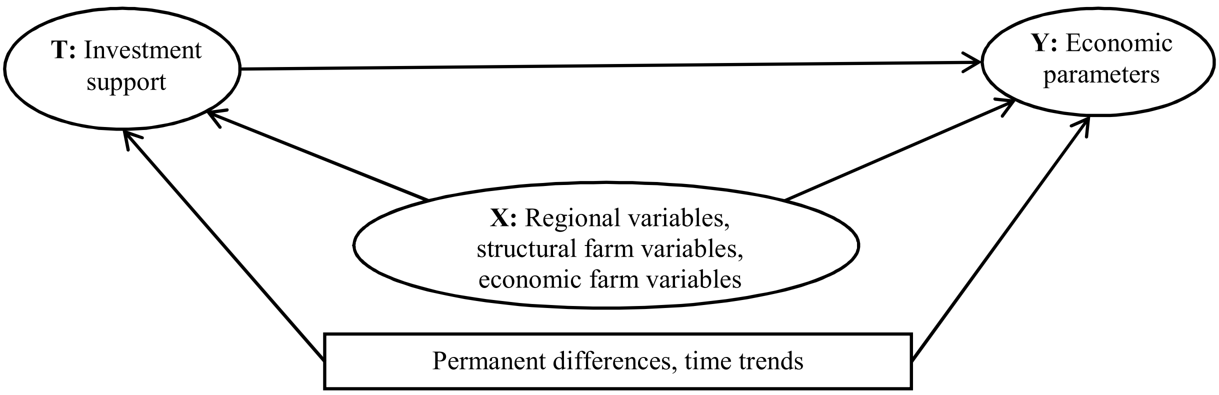

Figure 4: Identification of causal effects from supported investments on economic parameters (Source: own illustration)

[5] These investments are supported through the European farm-investment support programme, namely the "Modernisation of Agricultural Holdings", which is part of the Rural Development (RD) programme.

All in all, the results are fairly similar between the two applied models. It can be shown that a supported investment leads on average to a significant increase in production. This is indicated by positive effects with regard to UAA, LU and total output. Somewhat smaller effects are found for farm income and no effect for total income (including farm and non-farm income), showing that investing farms do not (or only to a very limited extent) succeed in converting increasing production into higher income. The results also indicate that investing farmers are not able to reduce their workload significantly more than their controls. They succeed, however, in increasing labour productivity, since increased production goes alongside almost stable workload levels. Furthermore we find that supported investments lead to a reduction in off-farm employment of farmers, an increase in land renting and a decrease in share of net worth.

Both models are able to increase the knowledge about heterogeneity of factors influencing the investment decision and the economic performance of farms. However, due to the high dependence on observable variables, both models might show some constraints. The principal missing variables are with regard to personal attitudes of the farm manager, including the needs and requirements of the farmer's family and the personal goal of the investment. These data requirements are so far not recorded in the used data sets.

In order to account for these missing data problems, a complementary analysis can be done using case-study survey data (Moser et al., 2015). Within this survey, investing dairy farms which are supported through the farm-investment measure are asked about their structural development from before to after the investment, as well as their goals regarding their investment. Using survey data, as well as standardised monetary data, normative modelling is applied in order to calculate the profit of the farms. The counterfactual situation is not built by existing non-investing farms but rather with hypothetic scenarios. The differences between these scenarios and the actual scenario, which is one with a supported investment, result in the effects caused through the investment and the support. In this case, the situation without investment, as well as the situation with investment but without support, are used as counterfactuals. Therefore, the effects can be divided into an "investment effect" and a "support effect". Furthermore, the effects on the microeconomic performance can be attributed to different goals and can add to the findings of the other models regarding farm investment and economic outcome.

Within this model controlling for variables, influencing the investment decision as well as the economic outcome parameters is not necessary, as the counterfactual situation is created artificially. However, this procedure shows constraints, as it requires many assumptions. Furthermore, the explanatory power of this model is limited, as the number of surveyed farms is usually low and farms and their investment are very specific. Where the selected farms should display typical agriculture and investments in the regional agriculture, some operational specification will still remain.

3.2 Effects on structural change (Model 3)

This model uses a similar design to the prior models and tries to estimate the effects of supported investment decisions[6] on structural change in agriculture (Kirchweger and Kantelhardt, 2015). Within Model 3, we use a conditional difference-in-difference estimator and apply a DCM approach which is described above (see Formula 7). This procedure again allows control for observable covariates but also for permanent differences of treated and controls, as well as for time trends like price fluctuations. However, this model differentiates from the above models, as it does not simply apply this formula to one time period; instead, it calculates the average treatment effect on the treated for one to nine years after the investment. This procedure allows us to show the dynamics of the estimated effects (see Figure 5). Such dynamic analysis of farm investments is useful for measuring the full implementation success of investments. To do so, the model uses data from the Integrated Administration and Control System (IACS) for a time period of 11 years. The data set only records structural variables but contains data from almost every farm in Austria.

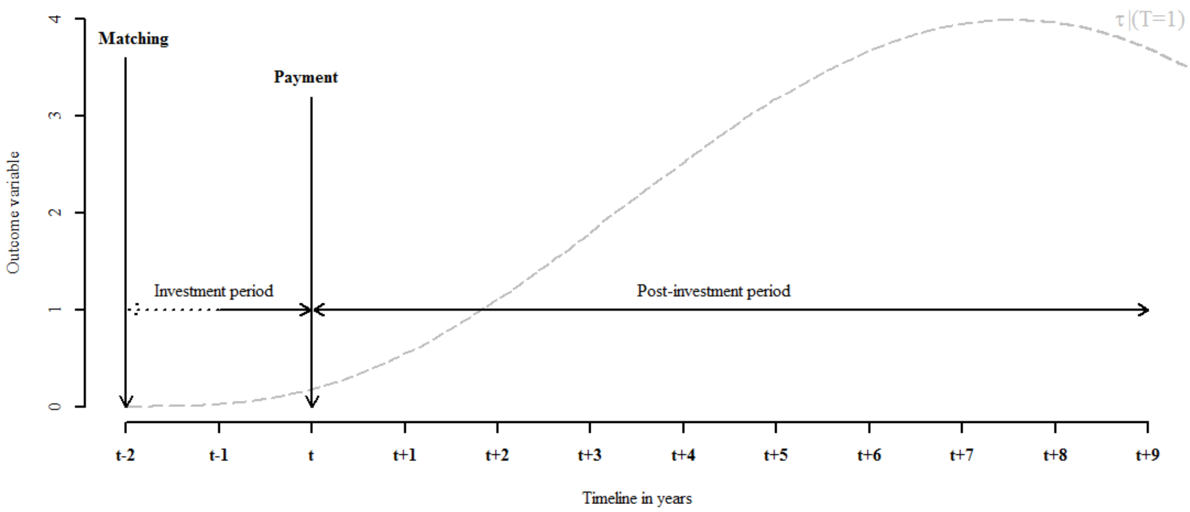

Figure 5: Schematic illustration of the model (Source: Kirchweger and Kantelhardt, 2015)

To model the effects of a supported investment decision on structural change of investing farms, similarly to the previous models, the investment decision is used as treatment dummy variable (T). In order to cover all relevant effects of government-supported farm-investment activities on structural change, two groups of outcome variables (Y) are used. First of all, the effects regarding farm size are estimated, since farm size is a major driver of structural change. In particular the variables total livestock units (LU), the total utilised agricultural area (UAA), arable area and grassland area are used. Secondly, as structural change not only appears in farm growth and supported farm-investment activities but might also cause changes of societal relevance, variables with significance for environment and rural development are considered. With regard to agriculture and environment, two aspects in particular are

[6] These investments are supported through the European farm-investment support programme, namely the "Modernisation of Agricultural Holdings", which is part of the Rural Development (RD) programme.

discussed: production intensity and production diversity. With regard to animal production[7], farming intensity is used as an outcome variable; measuring livestock units per ha UAA. A further outcome variable is farming diversity; measured with the Herfindahl index, where zero denotes full specialisation and one indicates full diversification of the farm. With regard to land use, the intensity of outcome variables in arable land (measured by a parameter adopted from Franzel (2013)), diversity on arable land[8] (again applying the Herfindahl index) and intensity in grassland[9] (expressing the share of extensive grassland area on total grassland area) is used. As organic farming and animal husbandry are of major importance in Austrian agriculture, entry rates into and exit rates from the organic farming programme and animal husbandry are analysed.

Based on theoretical considerations (and data availability), the following Matching covariates (X) are applied: in order to consider farm size, total livestock units (LU) and utilised agricultural area (UAA) are used; the farm type is expressed with the farm type for animal husbandry[10], the fruit and wine area and the diversity in animal husbandry. As Matching covariates with regard to site conditions, the mountain farm cadastre, belonging to a mountain farm zone, the share of grassland area and the intensity in grassland are used. Furthermore, the variable for the individual federal states of Austria is included. In addition, the selection of Matching covariates must consider all aspects which might influence the selected outcome variables (Morgan and Winship, 2010). The outcome variables for farm size might be shaped by pre-investment farm-size covariates, as well as by covariates regarding site conditions. Diversity and intensity parameters are highly dependent on farm type, site conditions and the participation in other policy programmes. However, these aspects are already covered by the covariates for farm size, farm type and site conditions, as mentioned above. In addition, the participation in other policy programmes is relevant in this context, as agri-environmental programmes in particular imply certain diversity and intensity restrictions. Therefore, the participation of the farm in organic farming and other agri-environmental measures is considered. In order to measure the entry and exit rates of farms in organic farming and animal husbandry, the model controls for their organic farming and animal husbandry status prior to the investment using the covariates organic farming and farm type in animal husbandry (see Figure 6).

[7] Estimation of both parameters is done only for farms with animal husbandry.
[8] Estimation of both parameters is done only for farms with arable land.
[9] Estimation of this parameter is done only for farms with grassland.
[10] The share of respective animal husbandry species is >50%. The farm types are always related to the data of the Matching year (t-2) and might change during the observation period.

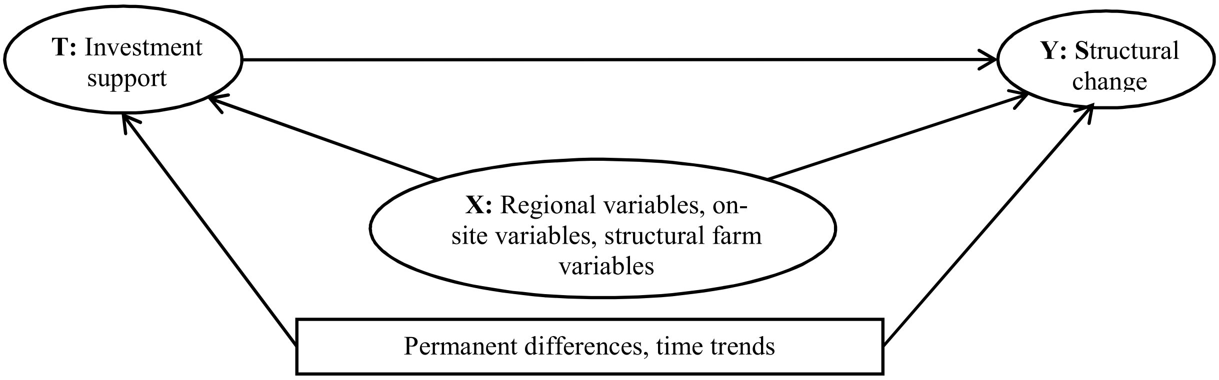

Figure 6: Identification of causal effects from supported investments on structural change (Source: own illustration)

The results show, similarly to Models 1 and 2, that government-supported farm-investment activities foster significant farm growth measured in LU as well as in UAA. The fact that effects are higher for LU than for UAA indicates a restricted supply of agricultural land, which forces investing farmers to achieve farm growth first and foremost by intensifying their production. Furthermore, we observe little losses of diversity but positive influence on entry rates into organic farming due to supported farm investment. We also find that, in most cases, structural effects are not realised directly after the investment period but accumulate over a longer post-investment period. In addition, our results indicate that part of this accumulation already takes place during the investment period; this applies particularly to UAA, which tends to increase continuously over the entire observation period, whereas LU rises relatively moderately during the investment period and increases rapidly immediately after investment. As a consequence, livestock intensity tends to increase quickly in the first years directly after investment.

The model also shows that the dynamics of growth effects differ between farm types. Whereas growth effects accumulate over a rather long period of time on cattle farms, the effects on pig farms increase in the short term and even decline in the long term. On pig farms in particular, livestock units increase higher and faster than agricultural area, a situation which leads to higher intensities in livestock husbandry. In contrast to that, the intensification effect on cattle farms is comparably small. On cattle farms we also find a positive effect with regard to participation in organic farming.

The model particularly provides insights in the heterogeneity and dynamics of the effects. Therefore, the temporal development of structural effects can vary fundamentally with regard to farm types. Furthermore, we can conclude that care has to be taken in choosing the length of the observation period when the effects of investments are analysed. However, the application of the DCM approach is constrained with the dimension of the vector X. A high dimension might lead to a decrease in chances of finding similar control farms. As we can dispose of a large number of potential control farms (90,000) in comparison to treated farms, this constraint can be relaxed in our analysis. As a result of the data set used, the model is limited in explaining the decision to invest and to participate in the farm-investment scheme.

4 Modelling the effects of a low-input decision

In order to be competitive, dairy farms have to use inputs like labour, capital, land, fuel, fertilizer, pesticides, concentrate feed and purchased roughage as efficiently as possible to produce their outputs (Alvarez et al., 2008; Reinhard et al., 2000). The optimal amounts and combinations of these inputs are based on in- and output prices, farm characteristics and farmers' attitudes. In the case of the latter, farmers might, on the one hand, purposely follow the goal to maximise the quantity of the output – which usually requires the use of high amount of external inputs. On the other hand, farmers can pursue a system which aims to use as little as possible of external production inputs. This is referred to as a low-input farming system, and basically it tries to achieve this by optimising the management and the use of internal production inputs (Pointereau et al., 2008).

Whereas farms maximising the output aim to increase profits through economy of scale, the goal of low-input farms is to increase competiveness by minimising their costs (Alvarez et al., 2008). Next to cost reduction, this system shows greater independence to external markets and therefore leads to a reduction in price risk (van der Ploeg, 2003). This fact will be especially relevant in the future when markets are expected to get more and more volatile. Furthermore, it clearly shows positive effects regarding environmental efficiency (Bava et al., 2014), which especially occur at a local level (Müller-Lindenlauf et al., 2010). Similar to the investment case, this underlines the importance of such decisions for the competitiveness of the farm but also for societal concerns.

4.1 Effects on economic performance (Model 4)

With this model we try to estimate the economic effects of low-input decision[11] for dairy farmers (Kirchweger et al., 2014). In this case, we use bookkeeping data from Austrian farms and an observation period of six years. The low-input decision is defined as having lower expenditures in external inputs than other. The average treatment effect on low-input adopting dairy farms is estimated using a DCM approach which is based on Formula 4. Matching is applied in the initial year of the observation period, but the development of outcome variables is analysed for the whole observation period.

This model differs from the other, as the treatment variable (T) is not observable within the data set. In order to obtain this binary dummy variable, 1 for pursuing a low-input decision and 0 for not pursuing a low-input decision, we use a cluster-analysis approach to define the treatment variable. As this model aims to estimate the effects from a strategy using a low level of external inputs, the cluster analysis is based on three standardised input variables: first of all the expenses per livestock unit for concentrate feed (expenses for concentrate feed); secondly, the depreciation and maintenance costs for machinery as well as for machinery leasing and hired machinery work per hectare utilised agricultural area (expenses for machinery); and thirdly, the energy expenses per hectare, based on costs for electricity,

[11] In this model the term "treatment" is used for these decisions, "treated" is used for those farm which make these decisions and 'controls' refer to farms not making the decisions.

fuel, fertilizer and bought roughage. The resulting cluster with the lowest mean values in these variables is used as the “treated” group. Farms from all other clusters serve as potential control unit.

In particular outcome variables (Y) indicating farm size, farm income as well as family labour input are analysed. In the DCM procedure, we control for the observable variables (X) influencing farm income and/or the decision to select a certain strategy. Namely, these are mountain farm cadastre points, mountain farm zone, the share of grassland and the value for taxing real-estate based on government valuation (Einheitswert) per hectare land (the so-called “Hektarsatz”) as proxies for site quality and other site conditions. Furthermore, we control for the size of the farm by employing utilised agricultural area (UAA) (see Figure 7).

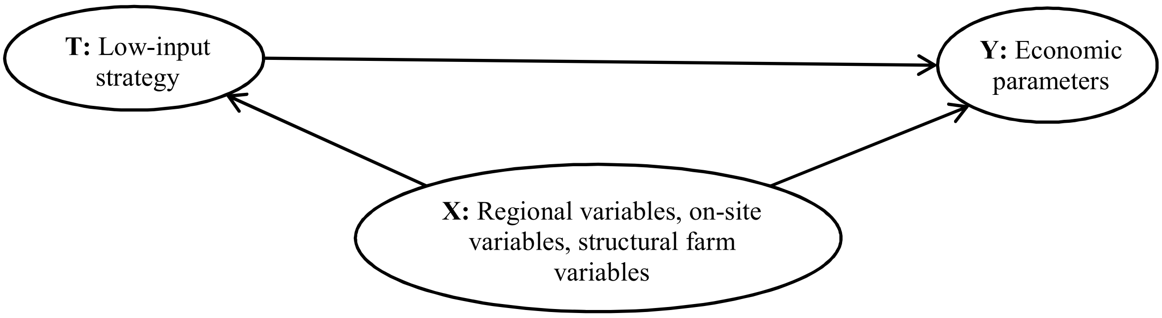

Figure 7: Identification of causal effects from low-input decisions on economic parameters (Source: own illustration)

The results indicate a negative effect on LU, which continuously rises during the observation period. As expected, the same trend is observable for total inputs and also with regard to total outputs. As both total outputs and total inputs have similar effects on low-input farming, the mean distance on farm income in the initial year is almost balanced and not statistically significant. This changes in the last year of the observation period, when a statistically significant negative effect is observable. Furthermore, we observe a negative effect for family-labour input and consequently no effect in farm income per family labour.

The approach used makes it possible to record farmers’ attitudes and management with regard to external input use, as well as their impacts on farm competitiveness in dairy farming. However, the model still lacks variables influencing the low-input decision choice. This might be due to missing data and might lead to hidden bias within the results. Furthermore, it has to be considered that Matching is only carried out in the initial phase of the time period and that estimated effects for the following years might be biased due to changes in the control variables.

5 Discussion and outlook

The basic objective of this thesis is to apply the Matching method in agricultural economics. In particular, it focuses on the estimation of effects with regard to supported investments and the decision to produce with lower amounts of external inputs (low-input). The applied models use data sets from Austrian agriculture and estimate the effects with regard to structural and economic outcomes at farm level. This section displays a comparative discussion of these results and the used models presented in the section above. It also draws some conclusions and it gives an outlook for further research.

5.1 Summary and discussion of results

As farm growth contributes to the competitiveness of farm holdings (Schaper et al., 2011) as well as to structural change (Weiss, 1999), we include structural outcome variables related to this in the applied models. All models applied within this thesis aim to estimate the effects on farm growth. The results in Models 1, 2 and 3 show that supported investments lead to an increase in agricultural area and livestock units, as well as in total monetary output from agricultural activities. These results are confirmed through similar studies for the Czech Republic (Medonos et al., 2012) and Germany (Michalek, 2012). When the low-input decision on dairy farms is analysed (Model 4), we find a noticeable decreasing effect for livestock units and consequently for the quantity of produced milk. These differences between low-input adopters and similar non-adopters increase in the long term, as non-adopters increase their livestock flock. Differences in livestock units, as well as in the quantity of produced milk, are also found between low-input pasturing farms and conventional farms in Baden-Württemberg in Germany (Kiefer et al., 2014).

However, knowing these results does not solve the question of whether or not the analysed decision succeeds in increasing a farm's profitability. Therefore, we also analysed the effects on economically relevant outcome parameters like farm income and the non-compensated family-labour input (Model 1, 2 and 4). Small but positive effects for farm income can be observed in the case of the farm-investment support. However, we also found no effect in reducing family-labour input, even though farmers also aim to reduce their labour input with investment (Sandbichler et al., 2013; Viaggi et al., 2011). This might be due to the fact that farmers do invest in labour-saving technologies but increase their production so much that no effect can be found. With regard to the adoption of a low-input strategy, we find a slightly negative effect on farm income but a decrease in family-labour input. The decreasing effect in family-labour input might allow the farmer to engage in non-farming activities in order to compensate for the losses in farm income.

Alongside the effects on the competitiveness farms, society is interested in the effects with regard to the production system and intensity. In this thesis, we refer to this by analysing livestock density, as well as the participation in organic farming. The results show that supported investments lead to an increase in both livestock density and organic farming (Model 3). Where the increase in livestock density conflicts with societal goals as well as the goals of the European RD programme, this is not a reason for an increase in organic farming. The latter occurs in particular for cattle farms where mostly large investments are necessary to comply with organic standards (Darnhofer et al., 2005). Furthermore, we also find that the share of organic farms is higher in the group of dairy farms with low-input strategy than in any other groups. This might indicate that low-input production is closer related to organic farming. As there is also a negative effect on livestock density, such a strategy decision might comply with the assumed societal concerns.

5.2 Discussion of models and outlook for further research

The Matching methodology estimates, similar to classical regression approaches, unbiased effects in the assumption that, under a given vector of observable variables, the outcome of one individual is independent of treatment (selection on observables). Even though this assumption is slightly relaxed by applying the average treatment effect on the treated, it is quite strong and requires the selection of all variables influencing the selection of a treatment or decision and the outcome variable (Caliendo and Kopeinig, 2008). If this is not the case, hidden bias remains in the effect. As Matching pairs treated and control units, there is hidden bias, when paired units look similar in their observable characteristics but still differ in their probability of treatment or decision-making. This means that there are remaining unobservable variables influencing the selection process as well as the outcome.

The result is limitations in applying Matching in the context of agriculture, where such selection processes are hardly understood and unobservable (Chavas et al., 2010). Such hidden bias is therefore especially relevant in the context of Austrian agriculture, where family farming is predominant and management decisions dependent on the unique relationship between farm enterprise and the farm household (Darnhofer, 2014). Furthermore, the analysis is challenged by heterogeneous managerial abilities and personal attitudes which have great influence on decision-making as well as on the economic or structural outcome parameters but which can hardly be observed (Chavas et al., 2010). Therefore, the modelling of agricultural decision-making with observable variables is challenging. This conclusion is also found in Schilling et al. (2014a), who analyses the effects of a farmers' opting for agro-tourism.

One possibility to reduce this hidden bias in observable research designs is to include qualitative, in-depth research in order to expand the data set. Questionnaires could also help to gain information about the necessity of making investments and therefore to model the investment decision (Viaggi et al., 2011). Another possibility in the future to solve the above-mentioned problem could be to have randomised experiments which would relax the assumption above. However, such designs will need further developments to be applicable in agricultural treatment and decision analysis in the future (Maart-Noelck and Musshoff, 2013). If it is not possible to observe or randomise the selection process, a large variety of methods exists, relying on the selection of unobservables and therefore relaxing the above-mentioned assumption (Imbens and Wooldridge, 2009). One method is the difference-in-difference estimator (Abadie, 2005), which is included in several models in this thesis but cannot be applied in every setting. As the difference-in-difference demands a before- and after-"treatment" situation, its applications in investment studies is appropriate but is hardly possible in studies which analyse strategic management decisions like low-input production.

It is also shown in this thesis that further bias in the estimates occurs as a result of a less-than-optimal length of the observation period. Model 3 indicates that an inaccurate observation period leads to an over- or underestimation of the effects from supported investments. Therefore, the effect on farm income in Model 1 and 2 might especially increase over time as the full production capacity can often only be reached a few years after the investment. Such dynamic developments are also reported in the literature (Bradley et al., 2010; Forstner, 2000; Hoffmann et al., 1997). Furthermore, Model 3 shows that the length of the observation period must be differentiated with regard to farm type, since the temporal development of structural effects can vary fundamentally with regard to farm types. Further dynamic analysis and models considering stratification of different farm types and observation periods must be carried out in order to account for such bias.

To summarise, the applied models show plausible effects of a policy programme as well as decision-making in agriculture. Furthermore, they give a good insight into the treatment selection and decision-making processes on farms. As the models are applied in a non/semi-parametric setting, this allows the opening of an integrative process, where researchers and policymakers can jointly reflect on causal exposures, data limitations and estimated effects. Such transparency is helpful in convincing stakeholders of the accuracy of an applied observational study (Rosenbaum, 2010). It can be concluded that methods such as Matching in combination with other techniques can be very helpful in estimating accurate results of governmental support, as well as farmers' decision-making.

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Part II: Publications

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2 List of additional articles and presentations by the author

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