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# Programming rural development funds – An interactive linear programming approach applied to the EAFRD program in Saxony-Anhalt

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# Programming rural development funds –
# An interactive linear programming approach
# applied to the EAFRD program in Saxony-Anhalt

# Programmierung von Mitteln
# für die ländliche Entwicklung –
# Ein interaktiver linearer Programmierungsansatz
# für das ELER-Programm in Sachsen-Anhalt

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## Abstract

Policies for rural areas have become an important but complex policy field in the European Union`s Common Agricultural Policy. The purpose of this paper is to report on a methodological approach pursued to model the allocation of EAFRD (European Agricultural Fund for Rural Development) funds in Saxony-Anhalt. We show how an interactive programming approach can be developed and used to support our partner Ministry of Agriculture and the Environment. So far, various key elements of the modeling approach have been specified: the definition of all relevant policy measures and funding options, the assessment of impacts on the regional objectives pursued, the definition of relevant lower and upper bounds, and the formulation of co-financing requirements and possibilities. Some first results reveal potentials for policy adjustment. After some more refinements and specifications, the model is to be used interactively with Ministry representatives for scenario calculations to support policy-making and strategy development for rural development in Saxony-Anhalt.

**Keywords:**     rural development, interactive programming, EAFRD,
multi-level co-financing, Saxony-Anhalt

## Zusammenfassung

Politik für ländliche Räume ist ein wichtiges, aber komplexes Politikfeld der Gemeinsamen Agrarpolitik in der Europäischen Union geworden. In diesem Aufsatz wird ein methodischer Ansatz vorgestellt, um die Verteilung von ELER-Mitteln (Europäischer Landwirtschaftsfonds für die Entwicklung ländlicher Räume) in Sachsen-Anhalt zu modellieren. Wir zeigen, wie ein solcher interaktiver Programmierungsansatz entwickelt und genutzt werden kann, um unseren Kooperationspartner, das Ministerium für Landwirtschaft und Umwelt, zu unterstützen. Derzeit sind verschiedene Schlüsselelemente des Programmierungsansatzes spezifiziert: die Definition aller relevanten Politikmaßnahmen und Finanzierungsoptionen, die Wirkungs-einschätzungen auf die in der Region verfolgten Ziele, die Definition relevanter Unter- und Obergrenzen und die Formulierung notwendiger oder möglicher Kofinanzierung. Einige erste Modellläufe zeigen das Potenzial für Politikanpassungen und -verbesserungen auf. Nach weiteren Verbesserungen und Spezifikationen soll das Modell interaktiv mit Vertretern des Ministeriums genutzt werden, um die Politikgestaltung und Strategieentwicklung für die ländliche Entwicklung in Sachsen-Anhalt zu unterstützen.

**Schlüsselwörter:**  ländliche Entwicklung, interaktive Programmierung, ELER, Mehrebenen-Kofinanzierung, Sachsen-Anhalt

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# List of abbreviations

| | |
|---|---|
| BMF | Bundesministerium der Finanzen |
| CAP | Common Agricultural Policy |
| DM | Decision maker |
| EAFRD | European Agricultural Fund for Rural Development |
| EAGGF | European Agricultural Guarantee and Guidance Fund |
| EC | European Commission |
| EEC | European Economic Community |
| EU | European Union |
| GAK | Gemeinschaftsaufgabe Verbesserung der Agrarstruktur und des Küstenschutzes |
| GDP | Gross domestic product |
| IACS | Integrated Administration and Control System |
| LB | Lower bound |
| LMF | Landesministerium der Finanzen |
| LP | Linear Programming |
| LUB | Lower and upper bound |
| MCDA | Multi-criteria decision analysis |
| MLU | Ministerium für Landwirtschaft und Umwelt |
| MODM | Multi-objective decision method |
| NSP | National Strategy Plan |
| NUTS | Nomenclature des Unites Territoriales Statistiques |
| RD | Rural development |
| RDP | Rural development program |
| RHS | Right-hand side |
| UB | Upper bound |
| VAT | Value added tax |
| VBA | Visual Basic Applications |

# 1. Introduction

Policies for rural areas have become an important policy field in the European Union's (EU) Common Agricultural Policy (CAP). Within the current financial period 2007-2013 a broad variety of policy instruments is supported by the European Agricultural Fund for Rural Development (EAFRD) providing up to 96.3 billion Euro in total (EC 2009a). In the way policy-makers design their rural development (RD) programs and decide about the allocation of funds to certain measures, they actively influence the development in rural areas, and thus, guide structural change in rural economies and the agricultural sector.

However, various problems have to be solved to allow for sound policy-making in this field. Key issues relate to the multitude of actors at multiple levels, to diverse objectives with limited operationalization and considerable trade-offs, and to the limited knowledge on policy impacts. Also, co-financing of several budgets, linkages between measures and budgets, and regional differences (preferences, measures, impacts, funding) have to be taken into account. Given this complex and rather intransparent decision environment, ultimately the questions arise if and by which means the overall process of RD policy-making can be supported effectively and how RD programs should be designed to achieve the political objectives pursued.

Within this paper, we seek to report on the methodological approach as well as on preliminary results of an interactive linear programming (LP) approach applied to the current EAFRD program in Saxony-Anhalt. The cooperation partner for this case study is the Ministry of Agriculture and the Environment in Saxony-Anhalt (MLU).[1] The collaboration started in October 2008 when the research team and the Ministry agreed upon a cooperation to strategically revise the entire EAFRD program of Saxony-Anhalt. Facing a difficult planning situation due to ever increasing problems to provide the demanded regional co-financing, the Ministry expressed a high interest in the analysis of scenarios such as the expected loss of the convergence region status and decreasing regional budgets. Thus, the model shall be used to analyze different policy options at the regional level. Besides this application, the case-study aims at the refinement of the methodological foundations for interactive programming using Linear Optimization and Solver-based Visual Basic Applications (VBA).

The remaining part of this paper is organized as follows: Section 2 will take a closer look at the institutional setting of the current European Agricultural Fund for Rural Development (section 2.1) and outline its important challenges and restrictions from a regional perspective (section 2.2). Section 3, then, is devoted to the specific methodological approach of facilitating EAFRD budget allocation in actual policy-making using interactive programming. Here, we will briefly explain the underlying philosophy of such an undertaking (section 3.1), sketch out the basic linear optimization model (section 3.2), and document the interactive

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definition of model parameters (section 3.3 and section 3.4). Based on this, section 4 will specify the structure of the linear optimization model in that we translate the model definition process into mathematical terms. Subsequently, results of the first computations are presented and discussed in section 5. Finally, we will draw some conclusions and give an outlook with regard to future tasks in section 6.

# 2.    European rural development policy

A European rural development policy in the sense of a multi-sectoral strategy to stimulate rural areas did not exist in the early days of the EU (then European Economic Community (EEC) and European Community) – not as a strategy or perspective nor as a name. In the first three decades since the foundation of the EEC in 1957, rural development policy was essentially understood as a sectoral issue dealing mainly with agricultural structures under the umbrella of the CAP. Singular policy measures such as payments for the modernization of agricultural holdings and the less favored area payments which were financed under the guidance section of the European Agricultural Guarantee and Guidance Fund (EAGGF) are examples of policy interventions which have their origin at this time. The policy field itself gradually evolved from these structural policies aiming at the agricultural sector towards what is since the Agenda 2000 known as the second pillar of the CAP. Under the Agenda 2000 existing policy measures in the frame of the CAP and the wider European Regional Policy were brought under a single regulation to apply across the whole of the EU for the period 2000-2006. In light of an ongoing structural change in general and in the agricultural sector in particular, the debate on what kind of regulatory framework is needed to effectively face the accompanying social, economic and demographic problems of rural areas has not stopped since.[2] The present highlight of this debate and central regulatory means of funding is the council regulation 1698/2005 on the support for rural development by the EAFRD (c.f. EC 2005). In what follows we would like to introduce this present regulatory framework in its most important elements (section 2.1) and outline the challenges arising from it from a regional perspective (section 2.2).

## 2.1    The regulatory framework

The current regulatory framework in RD policy is the result of a reform process which started in 2003 with the Mid-term review of the agenda 2000. The main elements of this reform can be summarized as follows: The promotion of rural development remained under the framework of the CAP, the financing modalities were simplified by the creation of a single financing and planning instrument (EAFRD), and the bottom-up approach was strengthened by integrating and mainstreaming the Leader method into the second pillar as a whole.

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[2]    The Mid-term review in 2003 represents one of the main footmarks in this debate. The main elements of this CAP reform are the introduction of decoupled single farm payments, cross compliance, increased funding for rural development and a reduction of direct payments in the first pillar (modulation) to finance the expanded second pillar (c.f. EC 2003).

Since then, the RD policy framework is based on a three-level programming process (table 1). Central means of legislation is council regulation 1698/2005 in which the overall frame is outlined and a set of measures eligible for EU funds is provided. In addition, the EU has set general priorities via so called Strategic Guidelines (c.f. Council of the European Union 2006). On the second level, each member state develops a National Strategy Plan (NSP) coherent to the council regulation itself and these guidelines. Here, the member states outline their specific objectives on the base of an evaluation of their particular economic, social and environmental situation, and specify the contribution of the EAFRD and national financial resources (c.f. EC 2005, article 11). The NSPs are intended to link and improve the coordination between European, national and regional priorities and actions and present – analogous to the community guidelines – a newly introduced requirement in the RD programming process.

**Table 1.**     **Three level programming process in RD policy-making**

| **EU** | **Overall priority setting**<br><br>(Council regulation and Community Strategy Guidelines)<br><br>→ Provide 'menu' of measures subject to co-financing |
|---|---|
| **Member States** | **Development of National Strategy Plans (coherent to EU)** |
| **Member States**<br><br>**or**<br><br>**Regions** | **Actual implementation**<br><br>Develop Rural Development Plans (RDPs)<br><br>→ Select measures best suited to address specific needs of programming areas |

Source: Own compilation.

The actual implementation mode of RD policy in the EU member states is set out in rural development programs (RDPs). These RDPs are either developed by the member states themselves for their entire territory or by the administrative regional entities of a member state for their respective regions. The RDPs as well as the NSPs need to be submitted to the European Commission for approval.

The overall objectives of the European rural development policy are defined in the EAFRD regulation (c.f. EC 2005, article 4). These are: Improving the competitiveness of agriculture and forestry (1), improving the environment and the countryside (2) and improving the quality of life in rural areas and encouraging diversification of economic activity (3). These objectives are implemented under the EAFRD via measures grouped into four priority axes.

The first axis comprises measures targeting the first objective (competitiveness) and, thus, is entirely orientated towards the agricultural and forestry sector. Amongst the 14 measures in this axis are five measures which aim at promoting knowledge and improving human

potentials such as vocational training and information actions (code 111)[3] and the use of advisory services by farmers and forest holders (code 114). Further six measures aim at restructuring and developing physical potential and promoting innovation. Typical examples here are investments for the modernization of agricultural holdings (code 121) and investments related to infrastructure in the agricultural and forestry sector (code 125). The remeaining three measures aim at the improvement of quality of agricultural production and products such as the support for farmers to participate in food quality issues (code 132).

The second axis comprises 12 measures which target the sustainable use of agricultural and forestry land. Thus, the second axis covers the objective two (land management) of the EAFRD regulation. Amongst the measures in this axis are exclusively area or animal based payments such as the compensation payments for less favored areas (code 211 and 212), the agri- and forest- environmental payments (code 214 and 225) and animal welfare payments (code 215).

The eight measures grouped in the third axis target objective 3 (wider rural development) and therefore have a clear territorial focus. Here, three measures aim at a diversification of the rural economy and promote for instance the diversification into non-agricultural activities (code 311) or the encouragement of tourism activities (code 313). Another three measures are meant to improve the quality of life in rural areas and focus on basic services for the economy and the rural population (code 321), village renewal and development (code 322) and the conservation and upgrading of the rural heritage (code 323). Further two measures aim at developing and strengthening the skills of the actors operating in the fields of axis 3 (code 331 and 341).

The purpose of the methodological axis four is to integrate the concept of the former community initiative Leader into the second pillar policy. The development and implemen-tation of innovative multi-sectoral rural development strategies in a bottom-up process incorporating public-private partnerships are at the heart of this approach. Therefore, on the basis of area based local development strategies so called local action groups implement measures out of the axes one to three. Additionally, two measures focus on transnational and inter-regional cooperation (code 421) and the skills acquiring process of the local action groups (code 431).

In order to reach a certain balance between the three objectives and the methodological Leader approach, the EAFRD regulation demands minimum allocations of EU funds to the axes (EC 2005, article 17). At least ten percent of the overall EAFRD contribution to a RDP needs to be assigned to axis one and axis three respectively. The minimum allocation to axis two should be 25 percent and five percent of the overall EAFRD funds need to be assigned to Leader implementations.

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[3]    Measure codes according to Commission Regulation (EG) No 1974/2006 (c.f. EC 2006).

Unlike the EU funds supplied in the first pillar of the CAP, all EAFRD funds are provided under the principle of co-financing. Thus, the EU contributes only a certain share of the overall financial support for a measure. All EAFRD funds need to be supplemented by further public national, regional and/or communal and private expenses resulting in a so called multiplier effect of public funds. The EAFRD co-financing rates differ along two criteria: the eligibility of a region to be supported under the convergence objective of the EU and the corresponding axis of a measure. The convergence objective comprises regions at NUTS 2 level whose gross domestic product (GDP) per inhabitant is less than 75 percent of the community average. In the case of axis one and axis three, 50 percent of the eligible public expenditures will be co-financed by the EU. This EU contribution increases for the case of convergence regions to 75 percent. In the case of axis two and four, 55 percent of the eligible public expenditure will be co-financed. As before, this contribution of the EU increases in the case of convergence regions – here to 80 percent.

The budget provided under the EAFRD for the financial period 2007 to 2013 amounts to 96.3 billion € in total (EC 2009a). A share of 17 billion of this overall amount results from modulation (15 billion) and further transfers from the first to the second pillar of the CAP due to market price support cuts in the tobacco, cotton and vine sector (2 billion) (EC 2009b). The original EAFRD budget (79.3 billion) is distributed amongst the member states following a number of different criteria (the amounts for regions under the convergence objective, past performances and the particular situations and needs based on objective criteria). Furthermore, particular regulations are in place for the distribution of funds resulting from modulation (c.f. EC 2005, article 69). Germany receives 9.4 percent (9.080 billion) of the overall EAFRD budget (EC 2009a). Due to its federal structure, Germany uses the possibility of regional programming. Thus, it distributes this overall budget amongst its administrative regions which are then responsible for the development of regional RDPs (coherent to the priorities set out by the EU and the German federal state) and the subsequent implementation of these programs. The next section outlines the particular institutional framework in the case of Germany and describes the challenges which arise from it.

## 2.2    Challenges from a regional perspective

The RD programming process is a complex task for a number of reasons: The multitude of actors and interest groups at multiple levels, rather limited knowledge on impacts, multiple conflicting objectives, complex financing modalities, only to name a few. However, most of these complexity features are in one way or another related to the multi-sectoral (and therefore highly interdisciplinary and multi-objective) nature of the RD policy field and/or arise due to the embedment of the policy field in the multi-level system of the EU.

In Germany, particular complexity with respect to financing modalities stems from the fact that the institutional RD framework is not only subject to the EAFRD regulation but also to the "Joint Action for Improvement of Agrarian Structures and for Coast Preservation (Gemeinschaftsaufgabe Verbesserung der Agrarstruktur und des Küstenschutzes, GAK)". In principle, RD and agricultural structures in the federal system of Germany are a subject-

matter of the regions. However, the GAK was established in 1969 to account for the objective of equal living conditions throughout the federal territory (c.f. article 72 constitutional law of the Federal Republic of Germany and article 1 Federal Spatial Planning Act – Raumordnungs-gesetz). Therefore, the federal government and the regions jointly decide on the design and financing of certain measures. Public budget expenses for all measures within the framework of the GAK are then shared between the federal state and the regions in a ratio of 60 to 40 percent. Since Germany used the GAK as a National Framework[4] for the regional RDPs, the two-level co-financing system changes for measures which fall under the frame of the GAK to a three-level system including financial contributions from the EU, the federal state and the regions. Figure 1 depicts the different co-financing possibilities for RD measures in Germany.

**Figure 1.        Co-financing modalities in a three-level system**
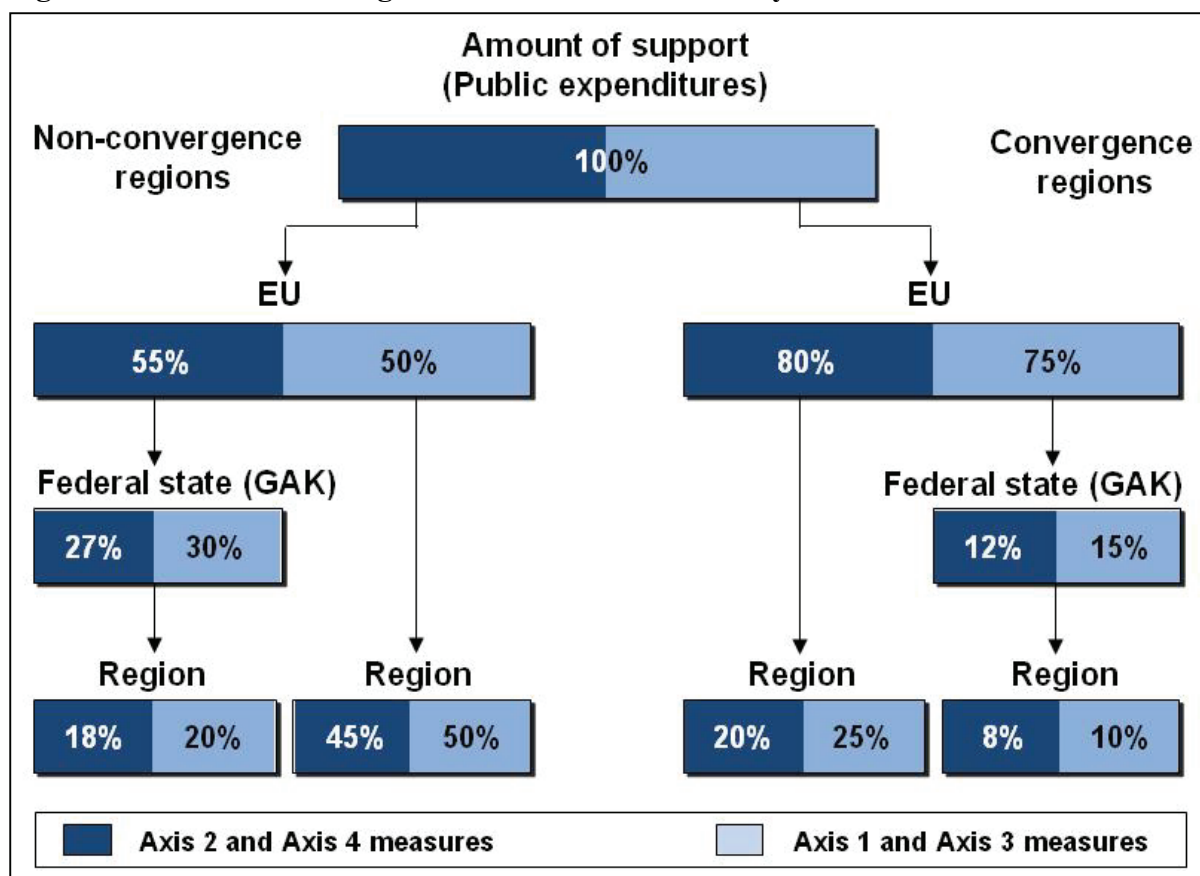


Source: Modified from Grajewski and Mehl (2008).

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[4]    According to the EAFRD regulation, member states with regional programming processes can choose to submit such a National Framework (c.f. EC 2005 article 15). This National Framework contains common elements for the regional RDPs and is meant to make regional programming easier and more coherent. Besides Germany, Belgium, Great Britain, Italy and Spain submitted single RDPs for their regions. Additionally, Portugal, Finland and France submitted a program for their mainland and additional regional RDPs for their islands (c.f. EC 2008).

The public budget expenditures consist of the financial contribution of the EAFRD plus the national public expenditures. These national public expenditures can be further disaggregated into the co-financing obligation borne by the federal state and the respective region. As depicted in figure 1, depending on the EU co-financing rate and whether a measure falls under GAK regulation, the regional financial responsibilities for a measure differ from eight percent (in case of GAK measures implemented in convergence regions) to 50 percent (in case of non-GAK-measures in non-convergence regions).

The overall public expenses for a measure are then supplemented by expenses of the beneficiaries. The overall volume of this multiplier effect depends on the EU co-financing rate, the particular support rate for a measure and the type of beneficiary. Beneficiaries can be either private or public entities such as communes. Since 2003, not only the expenses of the federal state and the regions are defined as public expenditures which form the overall national co-financing obligation but also communal expenses (c.f. EC 2005, article 2i). This modification in the regulatory framework has a number of interlocked consequences. First of all, it changes the composition of the national co-financing. In all cases where communes are beneficiaries they automatically take over "their share" of the national co-financing. Second, this modification practically leads to an increase of the support rate to 100 percent in the case of communes as beneficiaries. This, in turn, decreases the multiplier effect in these cases. To clarify the budget implications on the different administrative levels, we introduce in figure 2 the communes as a fourth administrative level and distinguish between private and communal beneficiaries and the GAK criteria.

As a consequence, the overall regional contribution to the national co-financing obligation depends on the actual share of communes as beneficiaries. This means that the tentative budget allocation laid down in the regional RDPs is based on estimates of these shares. Furthermore, figure 2 points out that the regional budgets can be substantially released by this provision which might be a good strategy in times of tight regional budgets.

Additionally to the outlined financing of a measure using EAFRD funds, regions (as well as member states in the case of not regional programming processes) have the possibility to allocate further expenditures to a measure (c.f. EC 2005, article 89). These additional national public expenditures are called top-ups and receive funds from the GAK if GAK measures are concerned. The specifications for communal beneficiaries (figure 2) do not apply in the case of national top-ups. Here, the federal state contributes to the expenses solely depending on the GAK status of a measure and regardless of the type and share of beneficiaries. Top-ups are part of the RDPs and, thus, also subject to approval by the EC even though no EAFRD funds are used.

**Figure 2.**    **Composition of the national co-financing obligation**
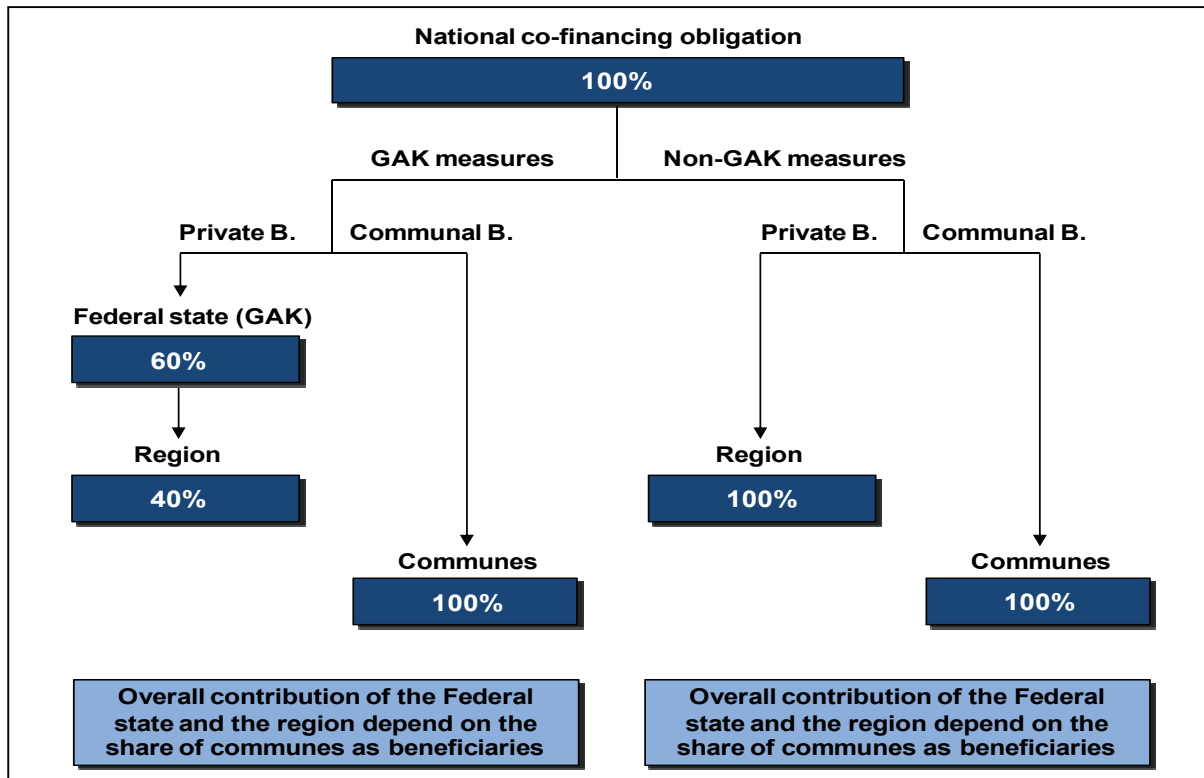


Source: Own compilation.

Summarizing the regulatory framework with regard to financing, the programming of regional RDPs is severely affected by the EAFRD and the GAK. Minimum contributions of EAFRD funds to the axes need to be considered, measures can be financed under different financial modalities at the same time and the way measures are financed imply different regional financial responsibilities. The outlined financing modalities constitute a particularly important framework since the overall financial situation of the regions in Germany is (with a few exceptions) increasingly tight. This holds particularly true for Saxony-Anhalt being at the top rank of all German regions (excluding the city states of Berlin, Bremen and Hamburg) with respect to public debts (c.f. Federal Statistical Office 2009: 595) and a prospect of a dramatic decline of revenues in the long run.[5] It is against this background that the programming of most regional RDPs is taking place emphasizing the need for objective-orientated budget allocation in RD policy.

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[5]    Among the most important reasons for high cuts of the regional budget in Saxony-Anhalt are increased interest charges and the decline of financial transfers coming from the federal state and the EU. The federal transfers will be substantially reduced due to the gradual decrease of the supplementary transfers for special burdens caused by the German division (Sonderbedarfs-Bundesergänzungszuweisungen) within the region equalization payments (Länderfinanzausgleich) (BMF 2008). The decreasing EU transfers refer to the expected loss of the convergence-region status and, thus, result in substantially less funding volumes in the frame of the European Structural Funds and the EAFRD. Furthermore, the severe demographic situation of Saxony-Anhalt adds to the problem of declining public revenues (LMF 2009).

# 3.    Programming rural development funds: methodological approach and data

In what follows, we would like to outline the methodological approach pursued in the case study, localize it in the context of the research on which it is based and document the process we have undergone so far. Figure 3 shows the multi-criteria decision analysis (MCDA) origin and summarizes the applied methodological approach in its main features: The interactive definition of a model, the integration of expert judgment to overcome the problem of limited impact information, the model itself which is based on linear optimization and implemented in Excel, and the subsequent interactive use of the model facilitated by VBA.

**Figure 3.        Methodological approach**
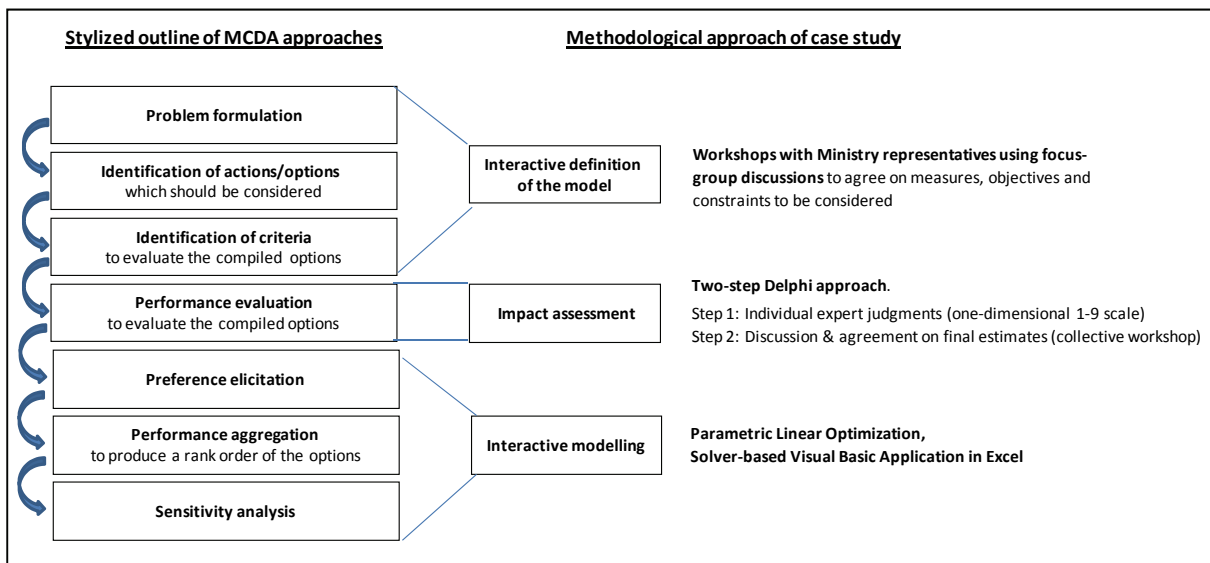


Source: Own compilation.

Since the overall approach belongs to the research area of MCDA and is heavily influenced by what Milan Zeleny (1980: 2) called the "interactive philosophy of mathematical programming" we will start with some sort of theoretical underpinning and localization (section 3.1) and introduce the linear optimization model (section 3.2). The following explanations are then devoted to the right hand side of figure 3. Here, we will document how the interactive definition of the model in terms of objectives, measures and constraints took place (section 3.3). Lastly, the generation and the categories of impact parameters are presented (section 3.4).

## 3.1    Interactive mathematical programming

As outlined above, the overall objective of the work undertaken is to analyze how RD programs can be improved and should be set to achieve the political objectives pursued. Given the multi-objective environment of RD policies and the quite large number of different measures which are implemented to reach these objectives, this means we are facing a classical multi-criteria decision analysis problem where a number of different alternatives (in our case: measures) are to be defined and evaluated against a set of criteria. A stylized step-wise process of such approaches is depicted in the left hand side of figure 3.[6] Following the problem formulation itself and the identification of alternatives and criteria, the evaluation of the alternatives with respect to each criterion is carried out. In order to produce a ranked order of the alternatives considered (that means to determine which alternative(s) is/are evaluated best overall) an evaluation of the criteria itself needs to take place and an aggregation procedure has to be applied. Here, the vast number of different MCDA approaches differs widely. Firstly, in terms of how, when and what kind of preference information from whom is elicited, and secondly, according to the specific method used for this aggregation.[7] At the end of MCDA approaches, sensitivity analyses are most of the time carried out to determine the impact of certain parameters on the results. The final step of decision processes in general, the actual decision in favor of one alternative (or a set of alternatives) and its implementation is in most cases not part of the decision-aiding process.

The methodological approach chosen for the case study is summarized in the middle part of figure 3 in which we split the process in three parts: the problem structuring phase (that is the definition of all input parameters for the model), the assessment of impacts (of the considered measures on the objectives defined) and the model use. Since the focus in our case lies on the optimal budget allocation of a set of policy measures we face a continuous solution space, and thus, apply a classical multi-objective decision method (MODM) for the overall performance aggregation: a linear optimization model. With respect to the preference information, we did not explicitly elicit preference information for the model beforehand but rather left this for the interactive modeling exercise together with the decision-makers (DMs).

The guiding principle for the approach is an interactive model definition and use of the model with real decision-makers in RD policy-making. This overall approach is executed in an iterative procedure in which dialogue phases (actively involving the DMs) alternate with phases of computation and model development (done by the analyst). Such an interactive procedure is strongly supported by the literature. It is believed to be "the most appropriate

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[6]   This outline is stylized for mainly two reasons: Firstly, because even though the bulk of approaches which use MCDA techniques largely work along these steps, the methods used for the accomplishment of e.g. the problem structuring phase differ widely and some approaches focus only on a few single steps. On the other hand this outline depicts a heavily stylized picture because all of the steps are by no means rigid or linear. The application of MCDA approaches in general incorporates feedback loops inbetween steps and is subject to looking back, questioning and retrospection from one step to another.

[7]   An example of such an aggregation method would be the Analytical Hierarchy Process (AHP) developed by Saaty (1980) which uses the so called Eigenvektor method. Another possibility is a linear optimization model.

way in obtaining the preferences of a decision-maker" (Kok 1986: 97). It constitutes a learning process (e.g. on trade-offs between conflicting objectives) that permits the decision-maker to better understand the system being analyzed and, thus, to take better informed and sensible decisions (c.f. Munda 2004). Further arguments in favor of interactive approaches are that through dialogue it is possible to set the focus on critical points and that convergence of opinions regarding critical parameters of the problem is possible (c.f. Kok 1986, Roy 2005).

The main objective of interactive approaches in general and our approach in particular is therefore not to find one optimal solution or to provide recommendations for direct courses of action. It rather lies in the improvement of decision-making quality and focuses on an improved structuring and transparency of the problem at hand (cf. Boots and Lootsma 2000, Geurts and Joldersma 2001, Munda 2004).

Along with this, researchers come increasingly to the conclusion that a lot more emphasis is needed on the initial formulation and structuring of the decision problem (e.g. Hajkowicz and Higgins 2008) and sensitivity analysis should be at centre stage (Kaliszewski 2004). Moreover, especially to support decision-making in the public sector, simple, clearly defined and flexible models should be used (e.g. Munda 2004, Walker 2000b). This concern and growing awareness is also backed by the agricultural modeling community that mostly uses relatively large and complex mathematical models. Brockmeier et al. (2008: 388), for instance, conclude that more pragmatic models and a consequent consideration of "the end users' needs in all stages of the modeling exercise" should be a paramount goal. Equally, Happe and Kellermann (2008) ascertain with regard to complex agent-based models considerable problems when it comes to the communication of model results and input parameters and note that an alleviation of the "black-box"-character of complex models needs to take place in order to provide appropriate policy advice. In line with this, Bankes (1992) as well as Walker (2000a) question the usefulness of large predictive models for complex policy problems and advocate for an exploratory use of computer modeling.

These concerns and recommendations in mind, we decided to approach the problem of arbitrariness in RD policy-making by applying a rather simple linear optimization model which is developed and used in an interactive way together with real decision-makers from RD policy-making.

## 3.2 Linear optimization model

The linear optimization model is implemented in Excel and has originally been developed by Kirschke and Jechlitschka (2002, 2003). Its generalized mathematical parts may be sketched out as follows:

Given the assumptions of constant marginal and average coefficients, a linear objective function

$$Z_1 = \sum_{i=1}^{m} z_1^i \, x^i$$

with:

$Z_1$          objective 1

$x^i$          budget expenses for measure i

i = 1, ..., n  index of the respective measures

$z_1^i$          constant marginal and average coefficient of the objective function describing the impact of the budget expenses for measure i on objective 1 (slope of the objective function)

can be defined. Since we are confronted in RD policy with a multi-objective environment, we consider j objectives and introduce a weighting factor $\alpha_j$ (with $\sum_{j=1}^{m} \alpha_j = 1$ ) for each of the objectives under consideration. Thus, we construct a single aggregated objective function with the weighted linear sum of the objectives and generate only one non-dominant "compromise solution" for each particular set of weights. The particular $\alpha_j$ can be arbitrarily chosen to look at the implications of several objectives on the allocation of funds or can be defined by the decision-makers representing their preferences. The resulting optimization approach can then be defined as follows:

$$\max_{x^1,...,x^n} Z = \sum_{j=1}^{m} \alpha_j \sum_{i=1}^{n} z_j^i x^i$$

subject to:

$$\sum_{i=1}^{n} a_r^i x^i \begin{Bmatrix} \leq \\ = \\ \geq \end{Bmatrix} b_r \quad for \ r = 1,...,k$$

and:  $x^i \geq 0 \ for \ i = 1,...,n$ .

The index r = 1,…,k describes constraints which can take the form of equations or inequalities, $a_r^i$ are the coefficients of constraint r for measure i, and $b_r$ denotes the right hand side of constraint r. Thus, in order to fully determine such a model, the objectives $Z_j$ and the measures $x^i$ need to be defined and the coefficients ( $z_j^i, a_r^i, b_r$ ) for all values of the indices i, j and r must be specified. In the following section we will document and explain how and what kinds of parameters were derived in the communication process with the Ministry.

## 3.3 Interactive model definition

The model definition took place in several meetings and workshops with Ministry representatives using either informal or more formalized focus group discussions. Furthermore, a two-step Delphi approach was executed where Ministry representatives estimated the impacts of the considered measures on the defined objectives. Table 2 provides an overview of the communication process with the Ministry of Agriculture and the Environment in Saxony-Anhalt.

**Table 2.        Process documentation**

| When and where | | | What | Participants |
|---|---|---|---|---|
| 1. Meeting | 21.10.2008 | MLU | Start up meeting<br>Exploratory talk about aims, perspectives, opportunities | Research team HUB (3)<br>MLU (2) |
| 2. Meeting | 16.12.2008 | MLU | Aims and expected results of the collaboration<br>Objectives to be considered in the model | Research team HUB (3)<br>MLU (7) |
| 3. Meeting | 17.02.2009 | HUB | Measures to be considered in the model<br>Financial modalities of the measures | Research team HUB (4)<br>MLU (2) |
| 4. Meeting | 04.05.2009 | MLU | Financial modalities of measures<br>Agreement on scorecard approach to generate impact parameters | Research team HUB (2)<br>MLU (2) |
| 5. Meeting | 08.09.2009 | MLU | Discussion and agreement on final estimates for impact paramters | Research team HUB (3)<br>MLU (6) |
| 6. Meeting | 02.11.2009 | MLU | Constraints to be considered in the model | Research team HUB (2)<br>MLU (14) |

Source: Own compilation.

So far, six meetings with representatives from the Ministry of Agriculture and the Environment took place during which the structure and the input parameters of the model were discussed. All of these meetings took place between October 2008 and November 2009 at the Ministry in Magdeburg except for one meeting which was held at Humboldt University. The initial exploratory talk took place in Magdeburg on a meeting held for that purpose. Here, the research team and the Ministry agreed upon a collaboration and discussed the aims of the study from the viewpoint of the research team and the Ministry. Subsequently to the start-up meeting three meetings took place in December 2008, February 2009 and May 2009 at which the basic input parameters for the model were derived and the approach to generate the impact parameters was discussed. The group of participants in these first four meetings consisted of our research group and two to seven higher representatives from the managing authority and the paying agency of the Ministry.

The last two meetings were designed as workshops dedicated to the discussion of and the agreement on final estimates for the impact parameters (September 2009, second round of the Delphi approach) and the shared exploration of restrictions to be considered (November

2009). These workshops were attended by up to 14 participants from the different Ministry departments responsible for the implementation and the payments. A computer and a beamer facilitated the visualization of the discussion and the results.

The model formulation in terms of objectives, measures and constraints was guided by the aim to realistically model the entire EAFRD program of Saxony-Anhalt. Therefore, the research team and the Ministry representatives agreed upon staying as close as possible to the current regulatory EAFRD framework and the specific situation in Saxony-Anhalt as outlined in the respective RDP. Table 3 summarizes the input parameters which were derived in the process with the Ministry and further points out which additional constraints have been incorporated in the model (constraints c to e). Thus, it represents a complete table of the input parameters considered in the model.

**Table 3.    Input parameters considered in the model**

| Objectives | Measures | Constraints |
|---|---|---|
| 1. Economic development of rural areas <br><br> 2. Creation of job opportunities in rural areas <br><br> 3. Environmental protection and nature conservation <br><br> 4. Administrative efficiency | 39 measures and measure groups of the current RDP of Saxony-Anhalt | a) Budget constraints on the level of the EU, the Federal state, the region and the communes <br> b) Measure-specific lower and upper bounds for the aggregated budget volume (LUB I) <br> c) Constraints deduced from the EAFRD regulatory framework (e.g. min. contributions of EAFRD funds to the axes) <br> d) Lower and upper bounds for the different measure specific financing and implementation options (LUB II) <br> e) Measure-specific lower and upper bounds which reflect the allowed deviation from the current allocation (LUB III) |

Source: Own compilation.

With respect to objectives, it was agreed upon considering the official regional objectives of economic development (1) and the creation of job opportunities (2) which were originally formulated in the planning process for the European Structural Funds and the EAFRD in Saxony-Anhalt (c.f. MLU 2009: 104ff.). Additionally, a third and fourth objective have been defined and included in the model. The third objective of environmental protection and nature conservation is a cross-sectional objective in the official planning process of Saxony-Anhalt. It has been explicitly considered by the Ministry representatives to account for future perspectives which are already represented in the CAP by the "Health Check". Given the debate about ever increasing administrative burdens, mainly due to the EUs' Integrated Administration and Control System (IACS), we considered as a fourth objective administrative efficiency indicating the administrative burden to implement the measures.

These four objectives have in the scope of the case study not been subject to in-depth operationalization. The research team and the Ministry representatives agreed upon a rather general definition of these objectives such as that the impacts of the considered measures with respect to objective one and two explicitly relate to the rural area in general and not only to the agricultural sector and that the estimates with respect to all objectives should depict net impacts. The fourth objective includes all administrative expenses which arise from the administrative process of the measures on the regional level. Here, costs primarily occur for personnel in charge of the implementation (e.g. administration of applications and payments or monitoring activities) or in form of expenses for contracted agencies. Other costs (e.g. administrative costs on the level of the EU and individual applicants or costs for the preceding measure composition) are not included.

With respect to measures, the model incorporates at present 39 different measures or groups of measures since some of the measures consist of several sub-measures each. See table 4 for a complete compilation of these measures. The question, what kind of aggregation level to choose for the modeling process was part of the discussion process in the meetings with the Ministry representatives. The final decision was to use the EU menu with the corresponding measure codes as it is also outlined in the RDP of Saxony-Anhalt (c.f. MLU 2009). Further disaggregation has taken place when the financial modalities for the single measures differ or when Ministry representatives wanted a further disaggregation since the single measures are too different to estimate their impacts in a group. A further disaggregation took place in case of five measure groups. This concerns in axis one the measures modernization of agricultural holdings (code 121) and the infrastructure related measure 125 which have been disaggregated to two and four measures respectively. In axis two the agro-environmental measures (code 214) have been disaggregated to six measures. And finally, two measures have been subject to further disaggregation in axis three: The measure group "Basic services for the economy and rural population" (code 321) is now represented by six measures and the measure "Conservation and upgrading of the rural heritage" (code 323) was subdivided into four measures. In comparison to the current version of the RDP of Saxony-Anhalt further modifications with respect to the considered measures have been made such that the research team and the Ministry agreed upon excluding three measures from the modeling exercise since they are not implemented yet and will (most likely) be excluded when the fourth amendment of the RDP will be submitted.[8]

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[8]   This concerns the measures 114 (Use of advisory services by farmers and forest holders), 224 (Forest-environment payments) and 225 (Restoring forestry potential and introducing prevention actions).

**Table 4.    Measures considered in the model**

| | Measure Code | Article* | Description |
|---|---|---|---|
| **Axis 1 (Competitiveness)** | 111 | 21 | Vocational training and information actions |
| | 121 | 26 | Modernization of agricultural holdings |
| | 121/I | | Agricultural investment support program |
| | 121/II | | Revolving Loan Fund for innovative investments in agriculture |
| | 123 | 28 | Adding value to agricultural and forestry products |
| | 124 | 29 | Cooperation for development of new products, processes and technologies in the agricultural and food sector |
| | 125 | 30 | Improving and developing infrastructure related to the development and adaptation of agriculture and forestry |
| | 125/I | | Infrastructure - Land consolidation |
| | 125/II | | Infrastructure - Construction of farming roads |
| | 125/III | | Infrastructure - Construction of forestry roads |
| | 125/IV | | Infrastructure - Improvement of water management infrastructure |
| | 126 | 20b | Restoring agricultural production potential damaged by natural disasters and introducing appropriate prevention actions |
| **Axis 2 (Environment and countryside)** | 212 | 36a | Payments to farmers in areas with handicaps, other than mountain areas |
| | 213 | 38 | Natura 2000 payments and payments linked to Directive 2000/60/EC |
| | 214 | 39 | Agri-environmental payments |
| | 214/I-a | | Market-oriented and site adapted land management: extensive production practices |
| | 214/I-b | | Market-oriented and site adapted land management: extensive grassland management |
| | 214/I-c | | Market-oriented and site adapted land management: organic farming |
| | 214/II | | Voluntary Natura 2000 commitments |
| | 214/III | | Conservation of genetic resources in agriculture |
| | 214/IV | | Voluntary water protection commitments (reduction of nitrogen surplus) |
| | 221 | 43 | First afforestation of agricultural land |
| | 223 | 45 | First afforestation of non-agricultural land |
| | 227 | 49 | Support for non-productive investments in forestry areas |
| **Axis 3 (Rural life and economy)** | 311 | 53 | Diversification into non-agricultural activities |
| | 312 | 54 | Support for the creation and development of micro-enterprises |
| | 313 | 55 | Encouragement of tourism activities |
| | 321 | 56 | Basic services for the economy and rural population (small scale infrastructure) |
| | 321/I | | Sewerage |
| | 321/II | | Drinking water |
| | 321/III | | Investments in small schools |
| | 321/IV | | Investments in childcare |
| | 321/V | | Renewable energy supply (local biogas and community heating systems) |
| | 321/VI | | Broadband internet |
| | 322 | 52b | Village renewal and development |
| | 323 | 57 | Conservation and upgrading of the rural heritage |
| | 323/I | | Drawing-up of protection and management plans relating to Natura 2000 sites and other places of high natural value |
| | 323/II | | Development of semi-natural water bodies |
| | 323/III | | Conservation of the rural landscape of hillside vineyards in winemaking areas in Saxony-Anhalt |
| | 323/IV | | Environmental awareness actions |
| | 341 | 59 | Skills acquisition and animation with a view to preparing and implementing a local development strategy |
| **Axis 4 (Leader)** | 421 | 65 | Transnational and inter-regional cooperation |
| | 431 | 59 / 61-65 / 63 | Running the local action group, acquiring skills and animating the territory |
| | 511 | 66 | Funding technical assistance |

 * Corresponding to the EAFRD regulation.

Source: Own compilation based on MLU (2009) and EC (2005, 2006).

With respect to constraints, the research team and the Ministry representatives agreed upon incorporating the key financial constraints resulting from the regulatory frame of the EAFRD and the specific arrangement of the RDP. Thus, in order to model changing available budgets on the different administrative levels or the impacts of a loss of the convergence-region-status, the detailed financial obligation borne by the EU, the federal state, the region and the communes had to be derived for each of the considered measures. As outlined in section 2.2, each measure can be implemented and/or financed via three different options and each of these options implies rather different financial modalities. Thus, the measure-specific co-financing parameters had to be further specified for these three implementation and financing options ("standard EAFRD mode", Leader and top-ups). The information regarding how the national co-financing obligations in each of these cases is split up between the federal state (via the GAK), the region and the communes has been collected in the discussion process with the Ministry (see meeting three and four in table 2) as well as by a thorough study of the respective legal acts (e.g. MLU 2008, 2009). The mathematical algorithm to derive the co-financing parameters is presented in section four. The entire matrix which depicts the co-financing modalities may be found in table A-1 (appendix).

Apart from the discussion about the financial constraints (meeting three and four), an entire workshop was dedicated to the exploration of lower and upper bounds (LUB I) restricting the budget volume allocated to a measure as a whole. These bounds represent logical conside-rations of the complex interplay between the maximum amount of land or animals (in case of area and animal based payments), the number of potential beneficiaries (in case of classical investment payments), the subsidy rate, and other regulatory settings of the respective measures. A complete list of the derived LUB is presented in table A-2 (appendix). To exemplify the rationale behind the LUB we take a closer look at measure 212. The amount of support for less favored areas depends on the eligible area and the particular payments per hectare. On average in the previous financial period, 128 000 ha per year received subsidies (Deimer et al. 2008: 99f.). The minimum amount of subsidy per hectare in this financial period is set at 25 Euro (MLU 2009: 277). Thus, under the assumption of a similar use of the measure by farmers, a lower bound of around 3 mio. € results. The upper bound for this measure has been set by the Ministry representatives at 70 million € for the entire financial period 2007-2013. The corresponding ten mio. € per year can be explained by the maximal number of farms which received funding over the last years (1001 farms) and the average amount of subsidies (10 500 €) paid (MLU 2009: 278).

Further constraints were included in the model but were not subject to discussion with the Ministry representatives since they were either directly deduced from the regulatory framework of the EAFRD[9] or included mainly for the reason to facilitate the interactive modeling session (c.f. LUB III in section 4).

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[9]   Constraints directly deduced from the EAFRD regulations include, on the one hand, constraints with respect to all measures such as the minimum contributions of EAFRD funds to the four axes. On the other hand we deduced measure-specific constraints such as the requirement to allocate maximal four percent of the EAFRD funds to measure 511.

## 3.4    Generation of impact parameters

Having defined the objectives and measures which are to be considered in the model, the next step was the generation of impact parameters. Given the rather weak and uncertain knowledge on impacts of RD policy measures on certain objectives, we derived these parameters using the existing RD expertise in the Ministry in Saxony-Anhalt. Executing a rather pragmatic two-step Delphi approach, representatives from 14 RD departments of the Ministry estimated in a first round the impacts of the considered measures using emailed scorecards. An example of such a scorecard (which also served as an example in the explanation sheets in the Excel files) is depicted in figure 4.

**Figure 4.           Scorecard example**



Source: Own compilation.

The Excel files were emailed to the Ministry departments in early May 2009. After two notification rounds 90 percent of the scorecards were received back at the end of June 2009. In a subsequent workshop in early September 2009 a subset of six Ministry representatives discussed the derived parameters and agreed upon final estimates.

The final results show a clear picture when aggregated over the axes (c.f. figure 5). Whereas the arithmetic means of the estimated impact parameters with regard to objective one and two are the highest in axis one (competiveness), they are the lowest in axis two (land management). Here, the Ministry representatives estimated the highest impacts with regard to the objective of environmental protection and nature conservation (objective three). The measures in axis two also got the lowest scores with respect to objective four.

**Figure 5.**      **Impact parameters (arithmetic means) grouped according to the axes**
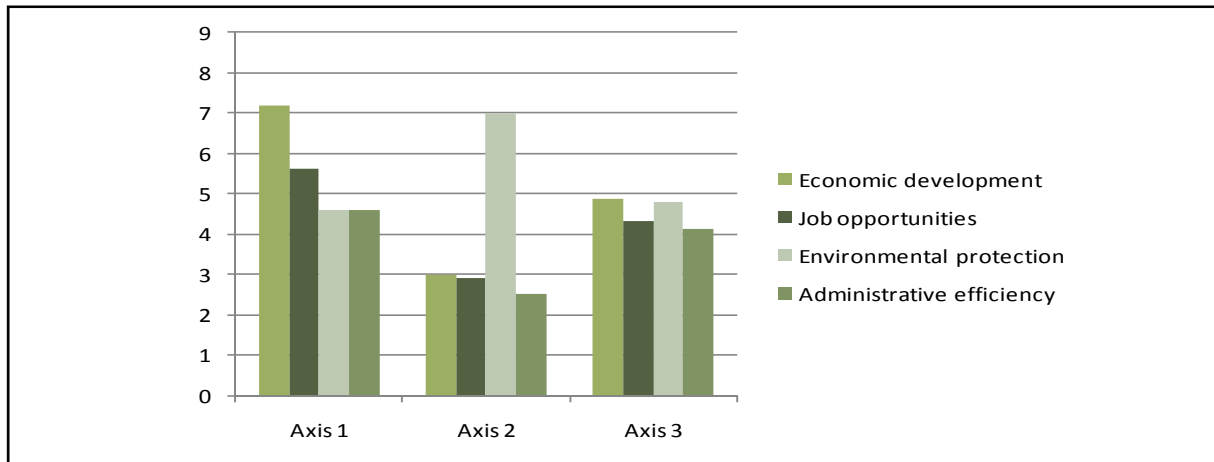


Source: Own compilation.

Concerning the funds directed to Leader groups, the Ministry representatives agreed upon a ten percent higher objective coefficient (compared to the normal implementation of the respective measure) with regard to objectives one, two and three and a ten percent lower objective coefficient with regard to the fourth objective. This tendency of the "Leader impacts" has already been observed in the first round of the Delphi approach – even though to different extents. After a detailed discussion whether the impacts of measures in the case of Leader implementations differ, and, if so, to what extent, the Ministry representatives finally agreed upon the explained "plus/minus ten % rule" as a starting point for the envisaged modeling exercise. According to the Ministry representatives, this lower administrative efficiency of measures implemented by Leader groups mainly results from a lack of experience and skills of Leader managers. Hence, Leader applications still require a substantial administrative effort with regard to additional instructions and considerable post-processing.

Figure 6 depicts the measure-specific impact parameters in case of the "normal" implementation mode and objective one to three.

**Figure 6.**      **Impact parameters for objective one to three**
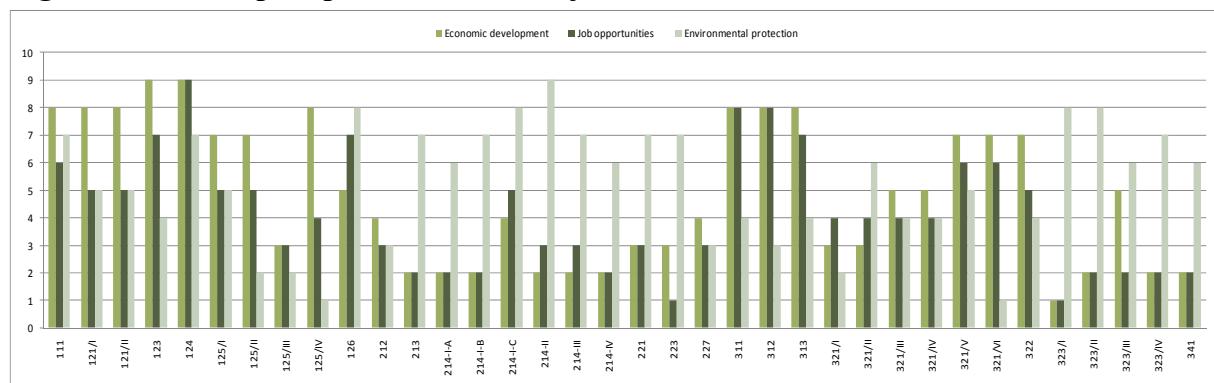


Source: Own compilation.

The observations according to the diagram showing the estimates for measures aggregated over the axes may generally be repeated when looking at the diagram of the impact parameters for specific measures. The ministry representatives assign high impact estimates for objective one (economic development) and medium to high scores with respect to objective two (the creation of jobs) to axis one measures. As for objective three (environmental protection), axis one measures get low to medium scores. Things look different when regarding axis two measures. Contributions to objective three are considered high, while the contributions to objectives one and two receive low scores. The diagram for the aggregated estimates of axis three showed intermediate scores for all three objectives. Looking at the scores for the specific measures gives a more differentiated picture.

Within the group of axis one measures the infrastructure measures (code 125) have to be noticed. While all of these measures receive notably low scores for the environment protection objective, the construction of forestry roads (code 125/III) receives low contribution scores for all three objectives. The restoration of agricultural production (code 126) also receives a comparatively low impact estimate for objective one, but this measure is regarded to be highly beneficial for objective three.

While the Ministry representatives predominantly assign high contribution estimates for objective three (environmental protection) to axis two measures, this is not true for the payments to farmers in areas with handicaps (code 212) and the support of non-productive investments in forestry areas (code 227). Both measures get low scores for objectives two and three and a lower medium score for objective one. Organic farming (code 214/I-c) is the only measure in axis two that is assigned medium impact estimates for objectives one and two as well as a high estimate for objective three.

The impact estimates for axis three measures present a mixed picture. As beneficial for the economic development and job creation are regarded the diversification measures (codes 311, 312, 313) as well as the infrastructure measures renewable energy supply and for broadband internet (codes 321/V, 321/VI) and village renewal and development (code 322). In general axis three measures receive low or medium contribution scores for objective three. However, the measures that are subsumed under conservation and upgrading of the rural heritage (code 323) and measure 341 (Skills acquisition and animation with a view to preparing and implementing a local development strategy) are given high impact estimates for objective three but low impact estimates for objectives one and two. An exception is the conservation of hillside vineyards (code 323/III) which is seen to give a medium contribution to objective one.

Figure 7 depicts the measure-specific impact parameters with respect to the objective administrative efficiency in case of the "normal" implementation mode.

**Figure 7.    Impact parameters for objective four**
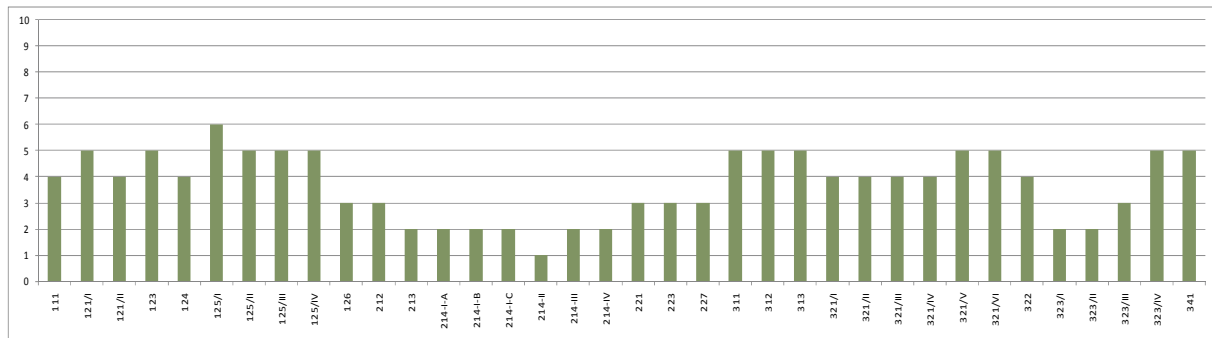


Source: Own compilation.

In contrast to the estimated target contributions of the specific measures for the objectives one to three, impact parameters for objective four show low to medium scores without exception; i.e. all of the measures considered in the model are regarded to impose rather high administrative burdens. This is predominantly an expression of the general notion and dissatisfaction with the IACS of the EU. The Ministry representatives argue that this system causes disproportionate administrative efforts. However, according to the Ministry of Agriculture and the Environment, it may be differentiated whether area or animal based measures or investment measures are considered. The former are associated with high administrative efforts (impact parameters between one and three); while the payments to farmers in areas with handicaps (code 212) get a low score, Natura 2000 (code 213) and agri-environmental payments (code 214) are assigned even lower scores. According to the Ministry of Agriculture and the Environment, the voluntary Natura 2000 commitments (code 214/II) impose the highest administrative costs. This is because in addition to the obligatory monitoring also time consuming risk analyses are required. Just like area based measures the investment based measures may also be differentiated. While they generally cause slightly lower administrative costs particular measures may be associated with additional efforts. E.g. in the case of vocational training (code 111) single farmers are the applicants which implicates a comparatively high effort for this measure. For the measures 321/I to 321/IV (Basic services for the economy and rural population) additional efforts are caused by the need for coordination with other agencies and authorities.


# 4.    Model specification

Within this chapter, the translation of the model definition process into mathematical terms is presented. According to the general LP model outlined in section 3.2, we seek to maximize an aggregated objective function subject to a number of constraints which were considered as important in order to realistically model the RDP of Saxony-Anhalt.

With respect to measures, the considered set of measures $x^i$ consists of several subsets since all measures can be grouped either into axis 1 (A1), axis 2 (A2) and axis 3 (A3) or belong to (R) which comprises the remaining rest of axis 4 (measures 421 and 431) and the technical assistance (measure 511). Thus, consider the set of $x^i$ as follows:

(1)     $M := \{1,..., 39\} = A1 \cup A2 \cup A3 \cup R$

with

(2)     $A1 := \{1,..., 11\}$

(3)     $A2 := \{12,..., 21\}$

(4)     $A3 := \{22,..., 36\}$

(5)     $R := \{37,..., 39\}$.

Each of these measures can be implemented and financed by k different implementation or financing options. To account for the different financial modalities associated with these options, a further disaggregation for each measure has taken place. With

(6)     $x^i := x_1^i + x_2^i + x_3^i = \sum_{k=1}^{3} x_k^i \quad for \quad i \in M$

we now arrive at a set of 117 decision variables with k=1 being the option to implement and finance a measure via the standard EAFRD mode outlined under the EAFRD regulations and the RDP specifications for axis one to three, k=2 being the option to implement a measure by a local action group under the Leader regulations (Leader), and k=3 being the option to allocate funds without a financial contribution of the EU (top-ups). Thus, the methodological axis four represents a subset of M and can be defined as follows:

(7)     $A4 := \{x_2^i \ for \ i \in M\}$.

As presented in chapter 3.3, it was agreed upon incorporating the following four objectives in the model:

$Z_1 =$   economic development of rural areas

$Z_2 =$   creation of job opportunities in rural areas

$Z_3 =$   environmental protection and nature conservation

$Z_4 =$   administrative efficiency.

With j = 1, 2, 3, 4 as the index for these objectives, we generated the objective coefficients $z_{jk}^i$ where

(8)     $z_{j1}^i = z_{j3}^i \neq z_{j2}^i$

and

(9)     $z_{j2}^i = z_{j1}^i + 0,1 z_{j1}^i$    *for j=1,2,3 and i∈M*

and

(10)    $z_{j2}^i = z_{j1}^i - 0,1 z_{j1}^i$    *for j=4 and i∈M .*

Thus, we consider the impact parameters to be different for the two different implementation options but independent of their financing source (statement 8). We generally consider a ten percent higher coefficient for Leader implementations in case of objective one to three (statement 9) and ten percent lower coefficient for Leader implementations in case of objective four (statement 10) (c.f. chapter 3.4).

With respect to constraints we consider three different kinds of simple lower and upper bounds (LUB):

(11)    LUB I:          $l^i \leq \sum_k x_k^i \leq u^i$    *for*    $\forall i$

(12)    LUB II:         $l_k^i \leq x_k^i \leq u_k^i$    *for*    $\forall i, k$

and

(13)    LUB III:        $l_{act}^i \leq \sum_k x_k^i \leq u_{act}^i$    *for*    $\forall i$

$$\text{with}\ \ l_{act}^i := (1-\beta) \sum_k x_{k\,act}^i\ \ \ and\ \ \ u_{act}^i := (1+\beta) \sum_k x_{k\,act}^i$$

where $x_{k\,act}^i$ represent the current budget allocation as set out in the RDP of Saxony-Anhalt and $\beta$ presents the allowed deviation (in percent) from this current allocation.

The LUB I, on the one hand, reflect the potential range of the budget volume allocated to a measure as a whole. These constraints were a major outcome of one of the workshops at the Ministry and are based on considerations and estimations of the DMs (c.f. section 3.3 and appendix A-2).

The LUB II, in contrast, restrict the budget allocated to the different financing and implementation options $x_k^i$. Hence, it is possible to account for, e.g., the financial commitments under the previous programming period (which have to be financed by the standard EAFRD mode k=1) or to restrict the budget allocation to a measure under the Leader implementation option k=2. Furthermore, through the LUB II it is possible to integrate specific    requirements    of    the    EAFRD    regulation    such    as    the    requirement

to allocate maximal four percent of the EAFRD funds to the measure 511 (c.f. EC 2005, article 66). Table A-2 (appendix) shows that only a few LUB II have been defined up to this point. The more precise definition of these LUBs is expected to happen in the interactive modeling session.

Equally to the LUB I, the LUB III are bounds for the budget volume allocated to a measure as a whole. Thus, depending on the actual values, one of them is always redundant. The LUB III reflect the allowed deviation from the tentative allocation as set out in the official RDP and can be set for all measures at once. Thus, an allowed deviation of ten percent results in a measure-specific LB of 90 and an UB of 110 percent of the current allocation. Past interactive modeling sessions revealed that it is a good strategy to start the modeling exercise by allowing for various deviations from the current solution, thus, developing a realistic structure of the constraints (LUB I) step by step.

Major other constraints relate to the minimum contribution of EAFRD funds to the four axes (c.f. chapter 2.2 and 3.3). The constraint

$$(14) \quad \sum_{i \in A1} x_1^i \ \geq \ MinEU\_A1 \quad with \quad MinEU\_A1 := EAFRD\_Budget \times \gamma_{A1}$$

accounts for the need to program the RDP in such a way that the share of the EAFRD funds directed to axis one is at least equal or exceeds a certain percentage of the overall EAFRD contribution to an RDP. This minimum contribution of EAFRD funds to axis one (MinEU_A1) is calculated by the overall EAFRD funds provided for Saxony-Anhalt (EAFRD_Budget) multiplied with an externally defined contribution share ($\gamma_s$ $with$ $s \in S := \{A1, A2, A3, A4\}$) which can be altered for the purpose of specific modeling exercises. In the frame of the current EAFRD framework $\gamma_s$ is set at ten percent in case of axis one and three (thus: $\gamma_{A1} = \gamma_{A3} = 0.1$), 25 percent in case of axis two ($\gamma_{A2} = 0.25$) and five percent in case of axis four ($\gamma_{A4} = 0.05$). The other four restrictions of this "minimum contribution block" can now be defined as follows:

$$(15) \quad \sum_{i \in A2} x_1^i \ \geq \ MinEU\_A2 \quad with \quad MinEU\_A2 := EAFRD\_Budget \times \gamma_{A2}$$

$$(16) \quad \sum_{i \in A3} x_1^i \ \geq \ MinEU\_A3 \quad with \quad MinEU\_A3 := EAFRD\_Budget \times \gamma_{A3}$$

$$(17) \quad \sum_{i \in M} x_2^i \ \geq \ MinEU\_A4 \quad with \quad MinEU\_A4 := EAFRD\_Budget \times \gamma_{A4} \quad .$$

Finally, the last block of constraints considered in the linear optimization model can be presented: the budget constraints on the different levels of the EU, the federal state, the

region, the communes and other entities.[10] As outlined in chapter 3.3, we derived for each $x_k^i$ the detailed financial obligation borne by the different (administrative) levels. As a result, mathematically speaking, we defined for each measure $x^i$ a matrix $C^i$ which comprises the financial contribution rate c on the level r for measure component $x_k^i$. The entire matrix

(18)   $\mathbf{C} = (c_{rk}^i)$

with

r = 1 = EU, r = 2 = federal state, r = 3 = region, r = 4 = communes and r = 5 others as rows and

(19)   $\displaystyle\sum_r c_{rk}^i = 1$

is presented in table A-1 (appendix).

As outlined in chapter 2, the overall amount of the national co-financing obligation ($\displaystyle\sum_{r=2}^{5} c_{rk}^i$) for a certain $x_k^i$ depends on a particular axes-specific EU co-financing rate and, thus, on $c_{1k}^i$. Since the expected loss of the convergence-status is one of the most interesting scenarios for Saxony-Anhalt, the model needs to account for changing co-financing rates on all relevant levels. Therefore we defined the EU co-financing rates $\delta_s$ ( $with\ s \in S := \{A1, A2, A3, A4\}$ ) and obtained for the EU level (r=1) the following parameters:

(20)   $c_{11}^i = \delta_{A1}$   $for$   $i \in A1$

(21)   $c_{11}^i = \delta_{A2}$   $for$   $i \in A2$

(22)   $c_{11}^i = \delta_{A3}$   $for$   $i \in A3$

and

(23)   $c_{12}^i = \delta_{A4}$   $for$   $i \in M$.

Since the additional national public expenses (top-ups) are generally not co-financed by the EU, it follows

(24)   $c_{13}^i = 0$   $for$   $i \in M$.

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[10] These "other entities" refer solely to measure 121/II (Revolving Loan Fund for innovative investments in agriculture). Here, the EU co-financing is distributed to a particular loan fund. The national co-financing obligation is in this case borne by the investment bank holding the fund. For further specifications see article 71 of the EAFRD regulation (EC (2005)), chapter 4 sub-section 3 of Commission Regulation 1974/2006 (EC 2006) and the detailed implementation rules outlined in the RDP of Saxony-Anhalt (MLU 2009: 210ff.).

The national co-financing obligation is then derived by subtracting the EU contribution from the overall national expenses $\left( 1 - c_{1k}^i = \sum_{r=2}^{5} c_{rk}^i \right)$ and can be disaggregated according to the eligibility of a measure to be supported under the frame of the GAK as well as the type and ratio of beneficiaries (c.f. chapter 2.2). The specification of these two criteria has taken place for all $c_{rk}^i$. Therefore, we can derive for each of the remaining levels r a formula to obtain the corresponding $c_{rk}^i$:

(25)   r=2:   $c_{2k}^i = \left( 1 - c_{1k}^i \right) \left( 1 - \%\_Com_k^i \right) GAK_{rFed}^i$   $for \ \forall i, k$ ,

(26)   r=3:   $c_{3k}^i = \left( 1 - c_{1k}^i \right) \left( 1 - \%\_Com_k^i \right) GAK_{rReg}^i$   $for \ \forall i, k$ ,

(27)   r=4:   $c_{4k}^i = \left( 1 - c_{1k}^i \right) \%\_Com_k^i$   $for \ \forall i, k$

Whereby $\%\_Com_k^i$ denotes the estimated percentage of communes as beneficiaries of $x_k^i$ and $GAK_{rFed}^i$ as well as $GAK_{rReg}^i$ present the measure-specific financial contribution share of the federal state and the region. Since top-ups (k=3) are solely financed depending on the GAK criteria we consider $\%\_Com_3^i$ to be zero regardless of the actual composition of beneficiaries. In case of measures which are implemented under the frame of the GAK the $GAK_{rFed}^i$ and $GAK_{rReg}^i$ values are 0.6 and 0.4. In case of non-GAK measures, these values change to zero ($GAK_{rFed}^i$) and one ($GAK_{rReg}^i$).

Due to the revolving loan fund implemented by Saxony-Anhalt to provide loans for innovative investments in agriculture (code 121/II, i=3), we need to introduce a fifth level. Since this applies only to one measure, all parameters at this level are set to zero except $c_{51}^3$ and $c_{52}^3$ which take the values 0.25 and 0.2 respectively.

To conclude the formulation of the budget constraints, we get a set of five budget constraints of the following form:

(28)   $\sum_{i \in M} \sum_k c_{rk}^i x_k^i \ \leq \ b_r$   .

An overview of the model structure is presented in figure 8.

**Figure 8.** **Model structure**

| | Axis 1 (A 1) | Axis 2 (A 2) | Axis 3 (A 3) | Rest (R) | |
|---|---|---|---|---|---|
| | M1 $\cdots$ | | | $\cdots$ M39 | |
| | $x_1^1 \quad x_2^1 \quad x_3^1 \cdots$ | | | $\cdots x_3^{39}$ | |
| $Z_1$ | $z_{11}^1 \cdots$ | | | $\cdots z_{13}^{39}$ | |
| $Z_2$ | | | | | |
| $Z_3$ | $\vdots$ | Z | | $\vdots$ | $\Big\} \rightarrow$ max |
| $Z_4$ | $z_{41}^1 \cdots$ | | | $\cdots z_{43}^{39}$ | |
| | | | | | >= LB I |
| | | | | | <= UB I |
| | | LUB | | | >= LB II |
| | | | | | <= UB II |
| | | | | | >= LB III |
| | | | | | <= UB III |
| | 1 0 0 1 0 0 ... 1 0 0 | | | | >= MinEU_A1 |
| | | 1 0 0 1 0 0 ... 1 0 0 | | | >= MinEU_A2 |
| | | B | 1 0 0 1 0 0 ... 1 0 0 | | >= MinEU_A3 |
| | 0 1 0 0 1 0 ... | | ... 0 1 0 | | >= MinEU_A4 |
| | $c_{11}^1 \cdots$ | | | $\cdots c_{13}^{39}$ | <= EU_Bud |
| | | | | | <= GAK_Bud |
| | $\vdots$ | C | | $\vdots$ | <= Reg_Bud |
| | | | | | <= Com_Bud |
| | $c_{51}^1 \cdots$ | | | $\cdots c_{53}^{39}$ | <= Other_Bud |
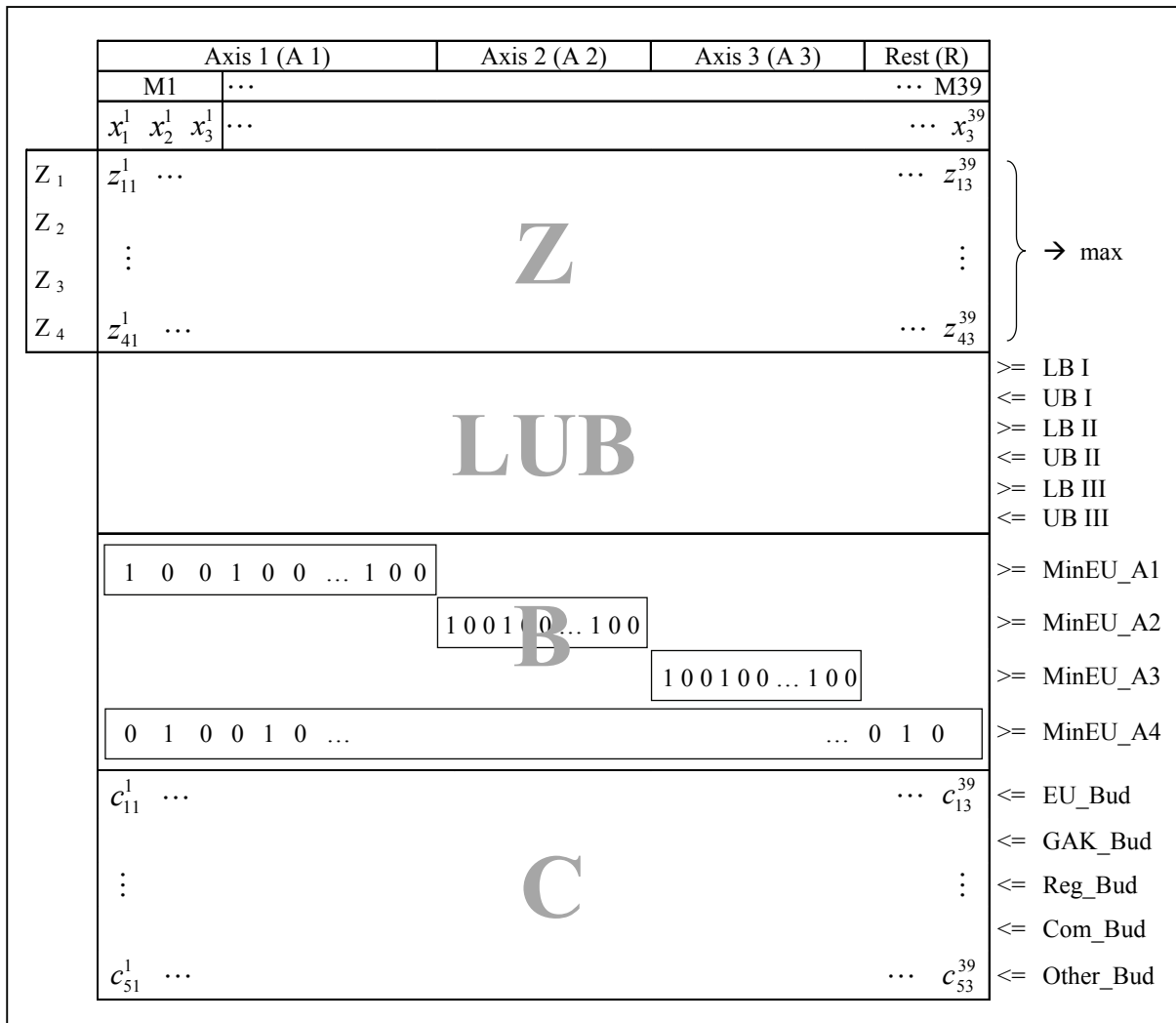
Source: Own compilation.

Whereas Z and C are the matrices for the impact parameters $z_{jk}^i$ and the financial contribution rates $c_{rk}^i$, LUB and B are particular 0-1-matrices where the relevant variables for the respective constraint may take the values one or zero.

Summarizing the model structure as explained above, we defined all relevant coefficients for all values for the indices i, j, k and r but externalized four variables that alter these coefficients when set to alternative states. With alpha (the weights assigned to the objectives) we can compose several distinct objective functions and exemplify trade-offs between these objectives. Beta can be used to keep the optimal solution derived by the programming approach somewhere close to the current allocation and is mainly a means to facilitate the DMs' familiarization with the model. Through gamma (the minimum contribution rates of EU funds to the axes) it is possible to account for changing priorities set by the EU and to analyze

the impacts which arise from that. Finally, through delta (the EU co-financing rate for each axis), all co-financing parameters can be changed at once which allows to analyze the impact of, e.g., the loss of the convergence region status in Saxony-Anhalt. All of these parameters can be separately modified. However, to facilitate the interactive model use, we developed a central worksheet in where all important input parameters can be set. This refers to the external variables explained above as well as to the remaining RHS (the lower and upper bounds and the budget constraints on the different levels ($b_r$).

# 5.    Preliminary results: current and optimized budget allocation

As mentioned above, the interactive modeling session together with the Ministry of Agriculture and the Environment has not yet taken place. Thus, instead of reporting on this process, we would like to present results of the first computations undertaken so far. In a first step, the current allocation of funds towards measures in Saxony-Anhalt is outlined (section 5.1). Optimizing this current allocation under a certain scenario yields a modified budget allocation which is then presented and discussed in section 5.2.

## 5.1    Baseline scenario

The tentative allocation of funds to measures under the frame of the EAFRD is defined in the Rural Development Program (RDP) 2007-2013 of Saxony-Anhalt (c.f. MLU 2009: 465ff.) and further specified in financial schemes of the Ministry of Agriculture and the Environment. According to these plans, an overall volume of 1.246 billion Euros (public expenditures) is assigned to the 39 measures considered in the model.[11] This overall budget volume consists of 809.02 million EAFRD funds and further 246.61 million public national co-financing expenses shared between the federal state (73.23 mio.), the region (114.79 mio.), the communes (55.09 mio.) and other entities (3.51 mio.). The remaining expenses of 190.49 million are top-ups whereof the federal state contributes 85.03 million and the region 105.46 million. Figure 9 depicts how these funds are currently allocated to the axes. The standard blue parts represent the EAFRD funds plus the national co-financing volume (EAFRD standard) and the light blue parts the volume of additional national expenses. The expenses which are planned for Leader implementations are shown as a column on its own (axis four). Additionally, all Leader implementations planned within axis one to three are added to the respective axis. For clarification, these expenses are all shown in dark blue parts even though they too are comprised of EAFRD funds plus the corresponding national co-financing obligation.

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[11]    According to the current financial scheme on which our calculation is based this overall amount sums up to 1.287 billion €. The difference of 40 million € is due to the explained exclusion of three measures. Additionally, our baseline scenario does not include the expenses planned under the economic stimulus package II (K-II-Paket) and further excludes the regional value added tax (VAT) expenses.

**Figure 9.** **Current financing of the EAFRD axes in Saxony-Anhalt (2007-2013)**
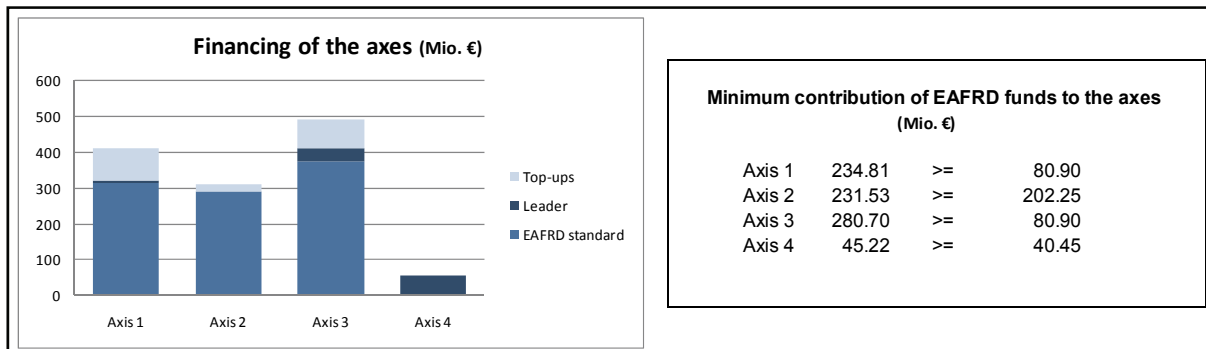


Source: Own compilation

According to the numbers displayed above, Saxony-Anhalt currently plans to allocate around 289.41 mio. € within the standard EAFRD mode towards measures in axis two compared to 313.08 and 374.29 mio. which are planned to be allocated to axis one and axis three. Comparing the respective shares of EAFRD funds (75 percent in case of axis one and three and 80 percent in case of axis two and four) to the axes-specific minimum contribution of EAFRD funds (ten percent in case of axis one and three and 25 percent in axis two) further reveals this prioritization of axis one and axis three (right hand side of figure 9). Saxony-Anhalt needs to assign equal or more then 80.90 mio. to axis one and three and at least 202.25 mio. and 40.45 mio. to axis two and axis four, respectively. A more detailed insight is provided by figure 10 depicting the current allocation of funds to individual measures.

**Figure 10.** **Current measure-specific budget allocation in Saxony-Anhalt (2007-2013)**
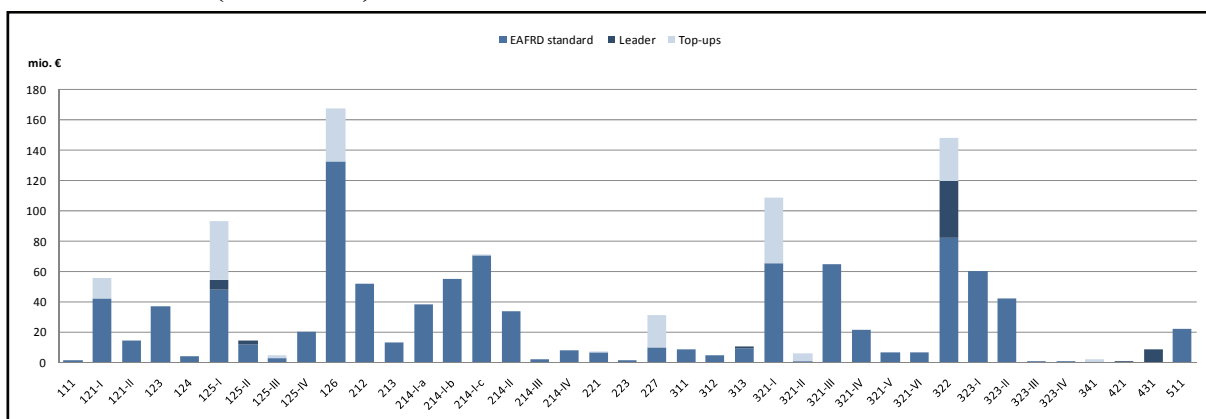


Source: Own compilation based on MLU 2009 and current financial schemes.

The measure-specific budget allocation clearly points out that the RDP of Saxony-Anhalt consists of several measures which receive relatively little funding. 14 out of the 39 measures

receive less than eight mio. €. In contrast, there are a number of measures which receive relatively high shares of the overall budget. Amongst them is most notably measure 126 which is in Saxony-Anhalt primarily implemented by supporting levee constructions and rerouting of levees (167.45 mio. € in total). Moreover, village renewal and development (code 322, 148.36 mio. €), the support of sewerage infrastructure (code 321/I, 108.63 mio. € in total) as well as payments for land consolidations (code 125/I, 93.14 mio. € in total) receive a substantial amount of the overall funds.

Expenses for Leader implementations are only planned within four measures of axis one and three. These are the infrastructure related measures 125/I and 125/II, the encouragement of tourism activities (code 313) and village renewal and development (code 322). According to Ministry representatives, these measures are particularly suitable for Leader groups and (based on experiences of the previous funding period) applications for other measures are highly unlikely even though they are generally possible. In order to generate plausible and realistic results, this is the explanation why in the model we restricted the budget allocation to Leader implementations to these four cases. In addition to the four measures within axis one and axis three Saxony-Anhalt intends to allocate 0.46 and 8.75 mio. € to the Leader measures 421 and 431.

## 5.2   Optimization of the current allocation

In a first modeling step, we optimize the current budget allocation considering only the two official equally weighted regional objectives of economic development (objective one) and the creation of job opportunities (objective two). Thus, we simplify the model and further set the values for the allowed deviation from the current solution to 100 percent. As RHS for the budget constraints we consider the currently used resources and all other external parameters are set according to the current EAFRD framework. Table 5 summarizes this scenario.

**Table 5.      Model parameters for the optimization of the current allocation**

$$\alpha_1 = \alpha_2 = 0{,}5 \quad and \quad \alpha_3 = \alpha_4 = 0$$
$$\beta = 100\,\%$$
$$\gamma_{A1} = \gamma_{A3} = 0.1 \quad and \quad \gamma_{A2} = 0.25 \quad and \quad \gamma_{A4} = 0.05$$
$$\delta_{A1} = \delta_{A1} = 0.75 \quad and \quad \delta_{A2} = \delta_{A4} = 0.80$$
$$b_1 = 809.017; b_2 = 158.257; b_3 = 220.366; b_4 = 55.085; b_5 = 3.509$$

Source: Own compilation.

For this scenario, the programming approach yields the following results. First of all, all budget constraints are binding meaning that the financial resources are fully used. Second, the overall value of the aggregated objective function increases from 5638.15 to 6866.39 (a plus of 21.8%) indicating a rather large optimization potential for the current budget allocation. Third, a substantial shift of budgets from axis two and axis three towards axis one and axis

four occurs. These shifts are further explained in figure 11. Whereas the diagram on the upper left shows the total amount of funds assigned to the axes, the lower two diagrams depict the changes which occurred with respect to the current allocation. Additionally, the table on the upper right shows the contribution of EU funds to the axes.

As a result of the programming approach axis one receives almost 600 €. The additional 187 mio. € assigned to the first axis are made up of funds previously assigned to axis two and axis three as well as to the two remaining measures of axis four (421 and 431). In case of axis two and axis three the minimum contribution constraint is binding. In case of axis three, this constraint is mainly met by the EU contribution to Leader implementations. The general shift of funds to the first axis also takes place with regard to top-ups. Here, only 39.01 mio. € remain in the third axis (decrease of 50 percent) whereas additional 70.92 mio. € are reallocated to measures in axis one.

**Figure 11.    Optimal financing of the EAFRD axes in Saxony-Anhalt (2007-2013)**
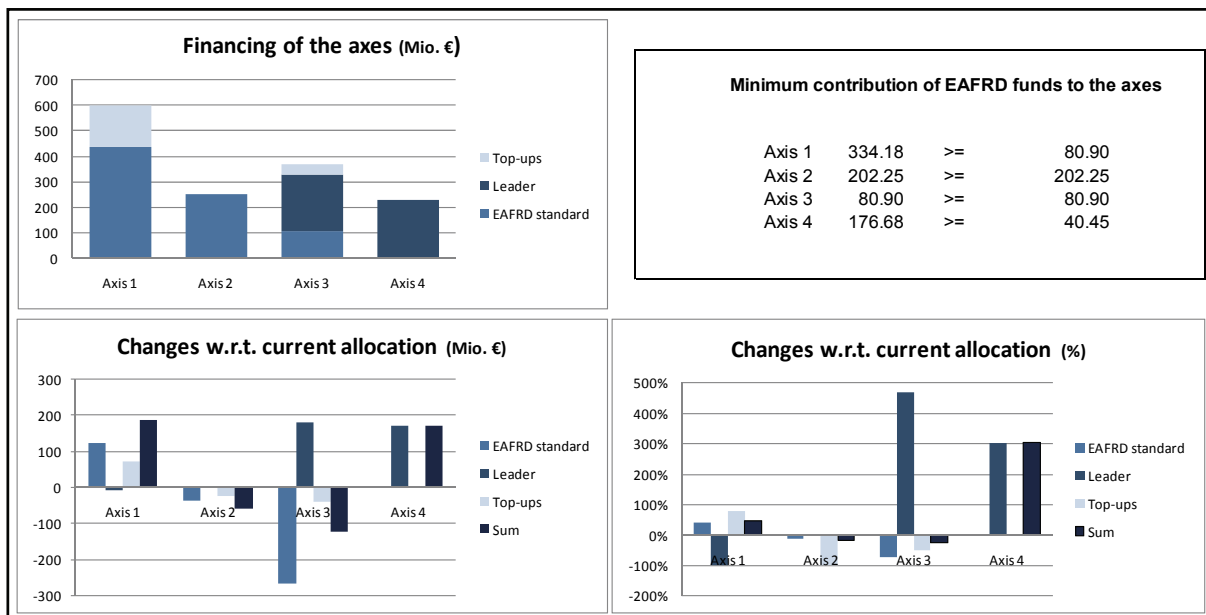


Source: Own compilation.

To get an overview of the corresponding measure-specific changes, figure 12 depicts these changes in percent for each aggregated decision variable $x^i$ and furthermore indicates the relevant lower and upper bounds in percent (LB and UB).

**Figure 12.    Measure-specific changes w.r.t. current allocation (%)**
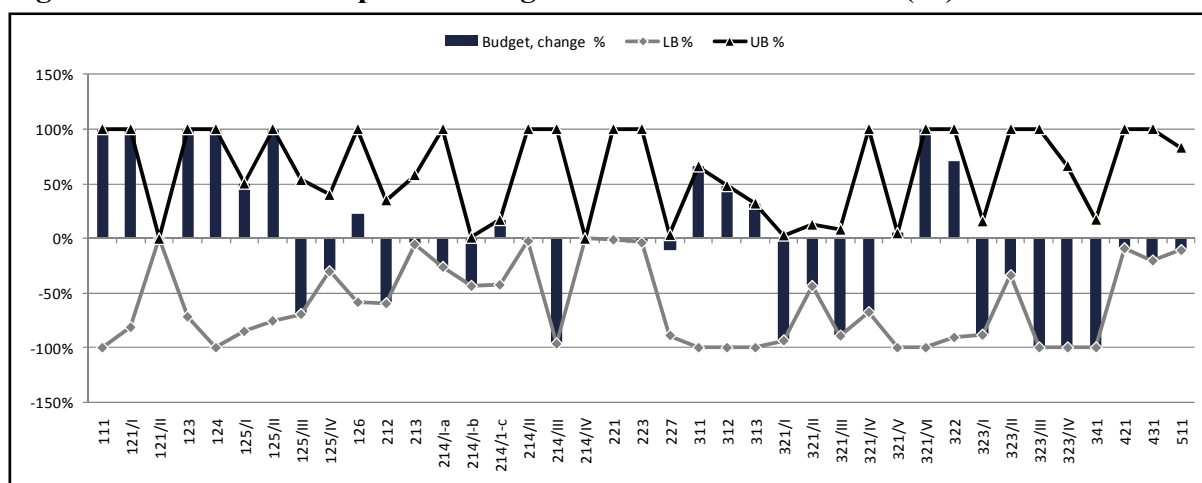


Source: Own compilation

As a result of the programming approach, the upper bounds are binding for twelve measures which receive substantially more funding than before. This applies to all measures in axis one with the exception of the infrastructure related measures of forestry road construction (code 125/III) and water management infrastructure (code 125/IV) as well as measure 126 (levee construction and rerouting). Measure 125/III got by far the lowest impact scores in axis one with respect to both objectives under consideration being the reason to be financed at its lower bound. Measure 125/IV got a notably high score with respect to objective one but only a lower medium score with respect to objective two (eight and four respectively). It is now financed at its lower bound. With medium to high impact scores of five and seven, measure 126 also received among the lowest scores in axis one. It is now financed by additional 22.4 percent. The stability check of the obtained solution revealed that the programming approach finds several optimal solutions for these two measures. Given an identical co-financing structure, the results show that from a purely financial perspective it is irrelevant how funds are reallocated.

All measures in axis two received notably low scores (between one and four) for the objectives under consideration. Here, the minimum contribution of EU funds is a binding constraint. As a result, the measure with the highest scores (organic farming, code 214/I-c) receives additional funds to fulfill this restriction. All other measures are financed at their lower bounds with the exception of the support for non-productive investments in forestry areas (code 227).

The measure-specific changes in axis three generally also reflect the corresponding impact parameters. The diversification measures 311, 312 and 313 target the creation of non-agricultural jobs and off-farm income opportunities and the measures 321/V and 321/VI represent infrastructure investments in broadband internet and renewable energy supply. All of these five measures were regarded as highly beneficial for the economic development and job

creation (impact scores between six and eight).Thus, they are now financed at their upper bounds even though these are highly restrictive as captured in figure 12 above. As with measure 126 in the first axis, investment support for village renewal and development (code 322) got notably medium to high impact scores for the two objectives under consideration. It now receives additional funding of about 70.4%. All other measures receive less funding and the lower bounds are binding. Taking a closer look at the depicted LB reveals that obviously no LB I and LB II have been defined for a number of measures (codes 111, 124, 311, 312, 313, 321/V, 321/VI, 323/III, 323/IV and 341) since in these cases the LB equal the LB III. Hence, all of these measures for which the LB is a binding constraint are not financed at all. This applies exclusively to measures in the third axis (323/III, 323/IV and 341) and would mean that they do not stay in the program.

A measure-specific budget allocation with respect to the different financing and implementation options $x_k^i$ is then depicted in figure 13 and 14 – further pointing out a number of interesting facts.

**Figure 13.** **Optimized measure-specific budget allocation**
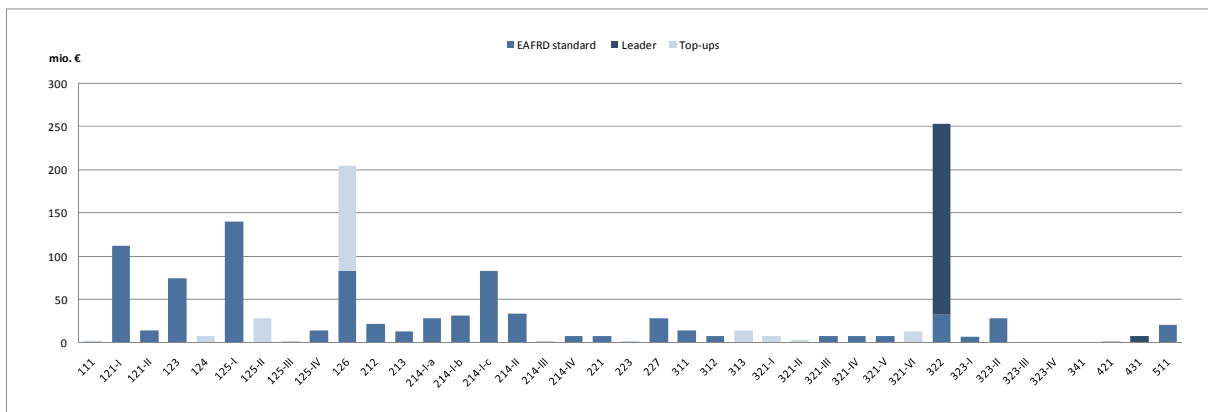


Source: Own compilation

**Figure 14.** **Changes with respect to the current allocation**
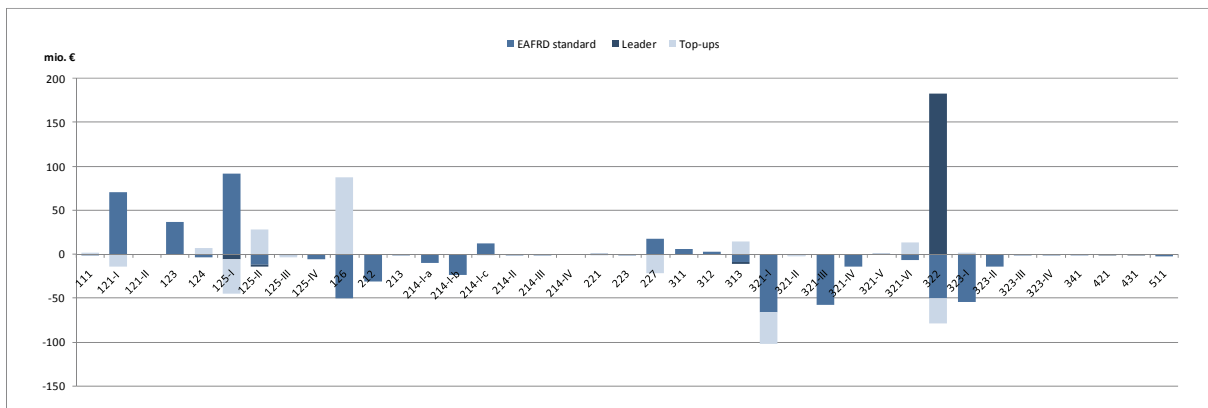


Source: Own compilation.

First of all, the high increase of funds assigned to axis one is obviously mainly a result of the increased funds directed to the measures 121/I, 125/I and 126. Given the high budget volume allocated in the reference scenario (the current allocation) and the non-binding UB I (c.f. appendix A-2), the allowed deviation of 100% from the current allocation (UB III) implies a much higher effect than, e.g., in the case of measure 111. Second, the increase of funds allocated to axis four solely results from the high share of additional Leader implementations in measure 322. Meaning that around 87 percent of the funds directed to village renewal and development projects are now directly linked to Leader implementation.

With respect to the financing modalities, the optimization yields an interesting result. Depending on the start values used for the optimization the Solver gives different solutions. Hence, figures 13 and 14 just present one solution. In this, the k-specific budget allocation with respect to the standard EAFRD mode (k=1) and the top-ups (k=3) differs widely compared to the current allocation. In other solutions, the financing modalities for seven measures (codes 121/I, 123, 125/III, 125/IV, 126, 321/VI and 322), in particular, vary. Most likely, this occurs due to the fact that we implemented the two different financing options (EAFRD standard and top-up) but assumed the impacts to be independent from their financing source. With $z_{j1}^i = z_{j3}^i$ we have a high number of equal objective coefficients in the model resulting in "an edge" of optimal solutions, meaning that under the given scenario and model specification one would be indifferent of whether to finance a certain measure by the standard EAFRD mode or by top-ups. Hence, with respect to financing modalities, the model does not yield conclusive results.

Summarizing the results of these first model runs, we notice on the one hand quite large optimization potentials and receive comprehensible results with respect to the overall budget volume to be allocated to measures. On the other hand, it became apparent that in order to generate more policy-relevant results a number of additional specifications have to be made. This refers, for example, to the high share of Leader implementations to measure 322 in our exploratory model run presented above. Such a result is a logical outcome of the model as it is presently defined. At the same time it is rather unrealistic since this share of Leader application will essentially never be reached. Hence, in a next step, one of the first modifications to the model will be the inclusion of upper bounds for Leader implementation. Specifications of this kind constitute a desirable "step by step familiarization" with the model. Moreover, they form the necessary basis for more sophisticated scenario analyses such as the parametrization of objectives or the impact analysis of reduced budgets.

It is possible that such specifications will also solve the problem of unstable solutions. Further specifications will lead to a more complex structure of constraints and, thus, to a modified solution space. However, in order to effectively use the model (be it in the interactive way or not) a certain stability of results needs to be achieved. The indifferences described above can, on the one hand, be interpreted as a gain of fiscal freedom. On the other hand, this interpretation might be a little too optimistic mainly for two reasons: First, because if such indifferences exist with respect to several measures (as it has been the case with respect to financial modalities in the exploratory example) the results will rather be interpreted as

inconclusive instead of opening up a wider scope of action. Second, consecutive scenarios cannot be analyzed and sufficiently interpreted if they are not based on stable reference scenarios. Hence, a future task is to explore possibilities to account for this problem.


# 6.     Concluding remarks and outlook

The purpose of this working paper was to report on the methodological approach pursued to model the allocation of EAFRD funds in Saxony-Anhalt. Additionally, we wanted to present the results obtained in the interactive model definition process with the Ministry of Agriculture and the Environment of Saxony-Anhalt. And, lastly, we present some preliminary model results in order to exemplify the current status of our work and to identify future tasks.

The main features of the programming approach have been outlined in section three and four: the interactive definition of the model, the generation of impact parameters, the linear programming model itself and the subsequent interactive use of the model facilitated by VBA. In the light of what has been presented in this working paper, a number of different conclusions might be drawn with respect to these features. For the interactive model definition process in general we draw a rather positive conclusion. The process seemed to be facilitated by the fact that the structure of the modeling approach was always presented in a matrix form and implemented in spreadsheets. Especially during the sensitive first phase of the collaboration it is important that the involved DMs understand the basic model structure in order to actively frame the multi-criteria problem at hand. Given that all participants were rather unfamiliar with modeling, the generally simple structure of a linear programming approach and the implementation in Excel (with its convenient data entry and editing features) seemed to be a good choice and allowed to get a greater understanding of how the problem is constructed step-by-step.

The generation of impact parameters, in contrast, might be one of the most controversial subjects with regard to the model definition. Using expert judgment to provide information on complex and generally poorly understood phenomena is quite common in MCDA even though the elicitation method should be designed carefully (c.f. Meyer and Booker 2001). By using the estimates of Ministry representatives (thus, defining the actual DMs as experts) we deviated from the request for independent experts as commonly claimed in the literature (e.g. Renn et al. 1993, Meyer and Booker 2001). Such an approach might be justifiable in general when considering the need to produce impact parameters in a rather limited time span. Furthermore, it seemed appropriate to consider the Ministry representatives as experts in the case of estimating the administrative burden. However, an important perspective is to carefully review the obtained parameters against findings from empirical data analyses in order to generate more reliable results. These reviewed impact parameters could subsequently be implemented in the model to compare and analyze the different model outcomes.

The particular linear optimization model developed to model the allocation of EAFRD funds has been presented in section four. It incorporates all key regulatory requirements of the current EAFRD regulation and depicts for each decision variable the co-financing obligation borne by the EU, the German federal state, the region, the communes and other entities. Thus, the model offers the possibility to realistically model and strategically revise an entire EAFRD program at the regional level. To facilitate the interactive model, all key policy variables (such as the EU co-financing rates) have been externalized in order to be able to quickly modify all corresponding parameters at once. Furthermore, a particular user interface has been developed using Visual Basic Applications. The approach developed has now to be used in interactive modeling sessions with the Ministry. Based on these modeling sessions, the appropriateness of these means will be evaluated.

One of the main model characteristics is the subdivision of the decision variables $x^i$ into k different financing and implementation options. This disaggregation has been considered as important since the overall amount of funds allocated to a measure comprises funds allocated under the standard EAFRD mode (k=1), funds linked to Leader implementations (k=2) and additional national funds (top-ups, k=3). Leaving the top-up option out would mean that a substantial amount of funds is not included in the model. However, considering it in the model yields a situation in which two-thirds of all objective coefficients are similar since one cannot expect the impacts to be dependent on their financing source. This poses a particular problem in terms of stability of solutions. Following the discussion on this subject in the previous section, one of the main future tasks is to explore possibilities to account for this problem.

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# Appendix

## Table A-1.  Co-financing matrix C

| | 111 | | | 121/I | | | 121/II | | | 123 | | | 124 | | | 125/I | | | 125/II | | | 125/III | | | 125/IV | | | 126 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EU | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 |
| Fed | 0.00 | 0.00 | 0.60 | 0.15 | 0.12 | 0.60 | 0.00 | 0.00 | 1.00 | 0.15 | 0.12 | 0.60 | 0.00 | 0.00 | 0.00 | 0.02 | 0.12 | 0.60 | 0.00 | 0.00 | 0.00 | 0.15 | 0.12 | 0.60 | 0.15 | 0.12 | 0.60 | 0.15 | 0.12 | 0.60 |
| Reg | 0.25 | 0.20 | 0.40 | 0.10 | 0.08 | 0.40 | 0.00 | 0.00 | 0.00 | 0.10 | 0.08 | 0.40 | 0.25 | 0.20 | 1.00 | 0.23 | 0.08 | 0.40 | 0.00 | 0.00 | 1.00 | 0.10 | 0.08 | 0.40 | 0.10 | 0.08 | 0.40 | 0.10 | 0.08 | 0.40 |
| Com | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Oth | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| | 212 | | | 213 | | | 214/I-a | | | 214/I-b | | | 214/I-c | | | 214/II | | | 214/III | | | 214/IV | | | 221 | | | 223 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EU | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 |
| Fed | 0.12 | 0.12 | 0.60 | 0.00 | 0.00 | 0.00 | 0.12 | 0.12 | 0.60 | 0.12 | 0.12 | 0.60 | 0.12 | 0.12 | 0.60 | 0.00 | 0.00 | 0.00 | 0.20 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.12 | 0.60 | 0.12 | 0.12 | 0.60 |
| Reg | 0.08 | 0.08 | 0.40 | 0.20 | 0.20 | 1.00 | 0.08 | 0.08 | 0.40 | 0.08 | 0.08 | 0.40 | 0.08 | 0.08 | 0.40 | 0.20 | 0.20 | 1.00 | 0.00 | 0.00 | 1.00 | 0.20 | 0.20 | 1.00 | 0.08 | 0.08 | 0.40 | 0.08 | 0.08 | 0.40 |
| Com | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Oth | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| | 227 | | | 311 | | | 312 | | | 313 | | | 321/I | | | 321/II | | | 321/III | | | 321/IV | | | 321/V | | | 321/VI | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EU | 0.80 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 |
| Fed | 0.12 | 0.12 | 0.60 | 0.15 | 0.12 | 0.60 | 0.15 | 0.12 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.02 | 0.60 | 0.00 | 0.00 | 0.00 |
| Reg | 0.08 | 0.08 | 0.40 | 0.10 | 0.08 | 0.40 | 0.10 | 0.08 | 0.40 | 0.09 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.25 | 0.20 | 1.00 | 0.25 | 0.20 | 1.00 | 0.02 | 0.02 | 0.40 | 0.00 | 0.00 | 1.00 |
| Com | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.20 | 0.00 | 0.25 | 0.20 | 0.00 | 0.25 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.16 | 0.00 | 0.25 | 0.20 | 0.00 |
| Oth | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| | 322 | | | 323/I | | | 323/II | | | 323/III | | | 323/IV | | | 341 | | | 421 | | | 431 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EU | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.75 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 | 0.80 | 0.80 | 0.00 |
| Fed | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.15 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Reg | 0.00 | 0.00 | 0.40 | 0.24 | 0.20 | 1.00 | 0.10 | 0.08 | 1.00 | 0.25 | 0.20 | 1.00 | 0.21 | 0.17 | 1.00 | 0.14 | 0.11 | 0.40 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 |
| Com | 0.25 | 0.20 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.03 | 0.00 | 0.11 | 0.09 | 0.00 | 0.20 | 0.20 | 0.00 | 0.20 | 0.20 | 0.00 |
| Oth | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Source: Own compilation.

# Table A-2.  Lower and upper bounds (LUB) I and II

## Axis 1

| Measure code | | LB I | LB II | UB I | UB II |
|---|---|---|---|---|---|
| 111 | EAFRD standard | 0.00 | 0.00 | 1000.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 121-I | EAFRD standard | 10.50 | 0.00 | 140.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 121-II | EAFRD standard | 0.00 | 14.04 | 14.04 | 14.04 |
| | Leader | | 14.04 | | 0.00 |
| | top-up | | 0.00 | | 0.00 |
| 123 | EAFRD standard | 10.50 | 0.00 | 350.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 124 | EAFRD standard | 0.00 | 0.00 | 70.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 125-I | EAFRD standard | 14.00 | 0.00 | 140.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 125-II | EAFRD standard | 3.50 | 0.00 | 70.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 125-III | EAFRD standard | 1.40 | 0.00 | 7.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 125-IV | EAFRD standard | 14.00 | 0.00 | 28.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 126 | EAFRD standard | 70.00 | 0.00 | 420.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |

## Axis 2

| Measure code | | LB I | LB II | UB I | UB II |
|---|---|---|---|---|---|
| 212 | EAFRD standard | 21.00 | 0.00 | 70.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 213 | EAFRD standard | 12.60 | 0.00 | 21.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 214-1-a | EAFRD standard | 7.00 | 21.22 | 70.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 214-1-b | EAFRD standard | 10.50 | 20.65 | 35.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 214-1-c | EAFRD standard | 14.00 | 26.82 | 56.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 214-II | EAFRD standard | 8.40 | 24.65 | 70.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 214-III | EAFRD standard | 0.00 | 0.06 | 21.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 214-IV | EAFRD standard | 0.00 | 7.82 | 0.00 | 7.82 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 0.00 |
| 221 | EAFRD standard | 2.03 | 5.21 | 14.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 223 | EAFRD standard | 1.12 | 0.00 | 7.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 227 | EAFRD standard | 3.50 | 0.00 | 32.20 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |

## Axis 3

| Measure code | | LB I | LB II | UB I | UB II |
|---|---|---|---|---|---|
| 311 | EAFRD standard | 0.00 | 0.00 | 14.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 312 | EAFRD standard | 0.00 | 0.00 | 7.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 313 | EAFRD standard | 0.00 | 0.00 | 14.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 321-I | EAFRD standard | 7.00 | 0.00 | 112.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 321-II | EAFRD standard | 3.50 | 0.00 | 7.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 321-III | EAFRD standard | 7.00 | 0.00 | 70.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 321-IV | EAFRD standard | 7.00 | 0.00 | 70.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 321-V | EAFRD standard | 0.00 | 0.00 | 7.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 321-VI | EAFRD standard | 0.00 | 0.00 | 105.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 322 | EAFRD standard | 14.00 | 0.00 | 490.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 323-I | EAFRD standard | 7.00 | 0.00 | 70.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 323-II | EAFRD standard | 28.00 | 0.00 | 140.00 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 323-III | EAFRD standard | 0.00 | 0.00 | 3.50 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 323-IV | EAFRD standard | 0.00 | 0.00 | 0.70 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |
| 341 | EAFRD standard | 0.00 | 0.00 | 2.10 | 1500.00 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 1500.00 |

## Remaing Measures Axis 4 and technical assistance (R)

| Measure code | | LB I | LB II | UB I | UB II |
|---|---|---|---|---|---|
| 421 | EAFRD standard | 0.42 | 0.00 | 3.50 | 0.00 |
| | Leader | | 0.00 | | 1500.00 |
| | top-up | | 0.00 | | 1500.00 |
| 431 | EAFRD standard | 7.00 | 0.00 | 28.00 | 0.00 |
| | Leader | | 0.00 | | 1500.00 |
| | top-up | | 0.00 | | 1500.00 |
| 511 | EAFRD standard | 20.00 | 0.00 | 40.87 | 40.87 |
| | Leader | | 0.00 | | 0.00 |
| | top-up | | 0.00 | | 0.00 |

Source: Own compilation.

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