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Editorial

The future of Bio-Based and Applied Economics

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Bio-Based and Applied Economics, the official journal of AIEAA (Associazione Italiana di Economia Agraria ed Applicata), was founded in 2011 and published the first issue at the beginning of 2012. BAE is now a well-established international journal, currently indexed in several scientific databases, including ISI-Web of Science and Scopus. Its citation performances have been ever growing and are expected to grow further during the next years. Years from 2012 to 2019 have been characterised by major changes in the profession and in the editorial practices. The choice to give the journal a thematic focus on one of most innovative aspects of the profession (the emerging Bioeconomy), as well as encouraging contribution from all the most traditional areas, has been a distinguishing appreciated choice. Several other new topics have meanwhile emerged in the economic literature, such as ecosystem services, climate change, digitalisation and the circular economy, accompanied by new approaches to study complex human, firms and markets behaviour. The academic context has changed even more dramatically. Publishing has become more competitive and provides continuous stimuli to operate in new and more effective ways. The Open access approach (chosen by BAE since the beginning) is becoming the new normal for publications; authors are expecting quick reactions and timely decisions; linkages with social media and diffusion of the papers published has become a key strategic feature.

BAE has always tried to keep pace with changes in the surrounding environment, but 2019 will represent a major milestone in this direction. This editorial is aimed at presenting the state-of-art of Bio-Based and Applied Economics (BAE) and the main changes that have led to a major reorganization of the Journal.

BAE continues to be a free open-access on-line journal promoted by AIEAA, and to welcome contributions on the economics of bio-based industries at large. The Journal is open to topics related to agriculture, forestry, fishery and food, and is also open to submissions of related disciplines, such as resource and environmental economics, consumer studies, regional economics, innovation and development economics.

In order to face the challenges listed above, and to deal with a fast-increasing number of submissions, coupled with a higher quality of submitted manuscripts, BAE has gone through a deep reorganization of the Board. The team is now composed by two Editors in Chief, responsible of the overall management of the Journal, one Managing Editor and three Associate Editors that oversee the peer-review process. The editorial team also

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includes an editorial assistant that helps managing submission, proofs, and dissemination of information related to BAE through media and social networks.

Apart from the renewal of the editorial structure, BAE has been interested by a major transition to a new online platform, which provides improved services for authors and readers of the Journal. The new platform is designed to be more user-friendly and to increase the visibility of manuscripts hosted in BAE.

The editorial strategy has been improved as well. The new Board is working to ensure a faster process from submission to publication. First, the Board has started a more explicit policy on **suggested reviewers**: each author is asked to suggest a list of potential reviewers (that do not have conflicts of interests) that are likely to be willing to review the submission. Second, the EIC and the AE are encouraged to complete a timely **review process** by following a protocol designed to having a first (editorial) decision within fifteen days and, for papers sent out for revision, a first round completed in three months. A third change is the inclusion of **junior reviewers**, a new strategy that is expected to have good impact on the process. In addition, the Board has started again to publish a very limited number of **invited papers**, authored by emerging or widely recognized experts. The rationale of publishing a limited number of invited papers is to guarantee space to host articles on topics that are considered of particular interest for the readers of BAE. The Board will also renew the tradition of open calls for **Special Issues** that will now be managed by guest editors, in charge of proposing the theme of the Special Issue and of managing the entire review process, under the constant supervision of the EIC. The Journal will encourage proposals for **Review Articles** that are likely to provide a valuable synthesis on the state of art on selected topics. Last but not least, BAE has now **social media** profiles (e.g. Facebook, LinkedIn and Twitter) that help communicating news and events related to the Journal. We believe these changes will provide a strong input to the growth of BAE.

The future of our profession will be certainly characterised by even faster changes in the topics, in the scale of analysis and in the methods able to match the emerging new problems. The dialogue with society will also become more important as well as the ability to valorise the role of research in a world characterised by a high amount of information, but difficulties with interpretation and growing complexity of processes leading to action.

This will affect the whole policy of AIEAA, looking at the perspective role of scientific associations as key actors in a context of worldwide transformations. And, of course of BAE, being one of the flagship initiatives of the Association. In turn, the ability of BAE to be an active actor in detecting and promoting scientific debate on such new issues, as well as taking up the challenges and the opportunities, and anticipating (or even leading) transitions, will be key for the future of the journal.

In such a dynamic context, the changes listed above are for sure not definitive, rather a key step for enabling BAE to ensure timely and proactive adaptations to the future. Further changes are expected already in 2020, with a partial renewal of the editorial board as well as with initiatives boosting the connection with the associates and with the scientific community.

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Full Research Article

How did farmers act? Ex-post validation of linear and positive mathematical programming approaches for farm-level models implemented in an agent-based agricultural sector model

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Abstract. This study evaluates linear programming (LP) and positive mathematical programming (PMP) approaches for 3,400 farm-level models implemented in the SWISSland agent-based agricultural sector model. To overcome limitations of PMP regarding the modelling of investment decisions, we further investigated whether the forecasting performance of farm-level models could be improved by applying LP to animal production activities only, where investment in new sectors plays a major role, while applying PMP to crop production activities. The database used is the Swiss Farm Accountancy Data Network. Ex-post evaluation was performed for the period from 2005 to 2012, with the 2003-2005 three-year average as a base year. We found that PMP applied to crop production activities improves the forecasting performance of farm-level models compared to LP. Combining PMP for crop production activities with LP for modelling investment decisions in new livestock sectors improves the forecasting performance compared to PMP for both crop and animal production activities, especially in the medium and long term. For short-term forecasts, PMP for all production activities and PMP combined with LP for animal production activities produce similar results.

Keywords. Agent-based sector model, farm-level model, linear programming, positive mathematical programming, ex-post validation.

JEL codes. C61, Q18, Q19.

1. Introduction

Agricultural policy models apply either linear programming (LP) or positive mathematical programming (PMP) approaches to analyse the impact of policy changes. The main advantages of PMP models over conventional LP models are that they guarantee exact calibration to the base year and avoid predicting overspecialisation without adding weakly justified constraints to the model formulation (Kanellopoulos *et al.*, 2010). Further

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advantages of PMP models are that they do not require large datasets and can be viewed as a bridge between econometric models, with substantial data requirements, and more limited LP models (Heckelei and Britz, 2005; Howitt *et al.*, 2012).

Studies evaluating the practice of PMP more than 15 years after Howitt published the first paper on this subject in 1995 show that PMP has become very popular in aggregated policy-decision support models (Garnache *et al.*, 2015; Heckelei *et al.*, 2012). The popularity of PMP is underscored by the fact that the majority of both European and non-European aggregated sector models[1] have used it for the calibration of crop and animal production since 2000.

However, PMP is much less popular in farm-level models. One reason for the limited use of PMP in this context is that farm-level models generally only take into account the activities observed during the reference period, even though new policies and market conditions allow farmers to undertake new production activities. To date, only a few farm-level models have used PMP to calibrate the crop activities of arable farms (Iglesias *et al.*, 2008; Kanellopoulos *et al.*, 2010) or both animal and crop production activities of dairy-farm models (Buysse *et al.*, 2007, Louhichi *et al.*, 2010). Iglesias *et al.* (2008) extended the PMP approach by incorporating new irrigation technologies for crop production activities in farm-level models using PMP.

Farm-level models implemented in agent-based models, which use mathematical programming methods to determine the production decisions of the farm agents (Happe, 2004; Röder and Kantelhardt, 2009; Lobianco and Esposti, 2010; Schreinemachers *et al.*, 2011), also prefer an LP approach over PMP. To our knowledge, there have been, to this point, no farm-level models implemented in agent-based models which use PMP.

The aim of this study is to assess the best mathematical programming approach for farm-level models implemented in the SWISSland[2] agent-based agricultural sector model on an empirical basis, i.e. going beyond theoretical considerations. We analysed the forecasting performance of a linear optimisation approach compared to a PMP approach. Because there is no single PMP approach in practice, but several different mathematical versions of PMP which all influence the forecasting performance of farm-level models, this study reviewed the most frequently used approaches for application in single farm models. To overcome limitations of the PMP approach regarding the modelling of investment decisions, we further investigated whether the forecasting performance of farm-level models could be improved by applying LP only to those production activities where investment in new sectors plays a major role. This is why we also validated an approach which combines PMP for crop production activities and LP for animal production activities. The ex-post evaluation was carried out for the period from 2005 to 2012, with the 2003-2005 three-year average as a base year. Over this period, Swiss agricultural policy changed decisively, particularly for milk and meat production. To cite an example, Swit-

[1] Examples of PMP-based, aggregated models representing either farm-type groups or whole regions are the German FARMIS model (Offermann *et al.*, 2005), the Italian FIPIM model (Arfini *et al.*, 2011), the Spanish PROMAPA model (Júdez *et al.*, 2008), the European CAPRI-FARM model (Gocht and Britz, 2011), the Swiss SILAS model (Mann *et al.*, 2003), the German-Austrian Glowa-Danubia Decision-Support System model (Winter, 2005), the European CAPRI-REG model (Britz and Witzke, 2014), the Dutch DRAM model (Helming, 2005), the USDA REAP model (Johansson *et al.*, 2007), the California SWAP model (Howitt *et al.*, 2012) and the New Zealand model NZFARM (Daigneault *et al.*, 2014).

[2] SWISSland' is the German acronym for 'Structural Change Information System Switzerland.

zerland concluded a free-trade agreement for cheese with the EU in 2007. The same year saw the country's gradual withdrawal from the milk quota system (Flury *et al.*, 2005), as well as the introduction of direct payments for dairy cows.

Section 2 of this paper gives a brief overview of an LP approach for single farm optimisation models and describes the most relevant PMP versions considered for the evaluation. Section 3 gives an overview of the SWISSland agent-based sector model and describes the different PMP and LP modelling options tested for the 3,400 single farm models implemented in the SWISSland model for the ex-post period from 2005 to 2012. By drawing a comparison with the historical pathway, Section 4 illustrates the forecasting performance of the single farm models at the farm and sectoral scales, and Section 5 provides conclusions as to how PMP and LP could be used in farm-based modelling.

2. Overview of LP and PMP approaches

Mathematical programming has been used in agricultural economics for more than fifty years. Mathematical programming starts from a decision rule of the decision maker, which determines the levels of the different variables when aiming to optimise the objective set by the decision maker (Hazell and Norton, 1986). Mathematical programming applied to farm models maximises the farm profit.

$$\max Z = \sum_i p_i x_i - c_i x_i \qquad (1a)$$

$$\text{subject to: } \sum_i A_{wi} x_i \leq B_w \text{ and } x_i \geq 0 \qquad (1b)$$

In Equation 1a, parameter Z denotes the farm profit to be maximised, p is the vector of product prices, c is the vector of variable costs, x is the vector of production levels and i is the index for the production activities. The optimal solution must fulfil the constraints in Equation 1b, where B_w is the available quantity of resource endowments w, and A is the demand of resource endowments of one unit of x. Mathematical programming models assuming constant marginal costs in the objective function became generally known as LP models. A main disadvantage of LP models is a tendency to overspecialise in crop production (Howitt, 1995). This was the main reason why Howitt (1995) developed models based on the PMP technique. Howitt *et al.* (2012; 245) describe PMP as a 'deductive approach to simulating the effects of policy changes on cropping patterns at the extensive and intensive margins. The term *positive* implies the use of observed data as part of the model calibration process'.

PMP models use information contained in shadow values of an LP model which is bound to observed activity levels by calibration constraints (Step 1). Based on these shadow values, a non-linear objective function is specified such that observed activity levels are reproduced by the optimal solution of the new programming problem without bounds (Step 2).

Many PMP-models use a quadratic, decreasing marginal gross margin function (Equation 2) that assumes increasing marginal costs in the objective function, whilst returns to scale remain constant. This functional form was proposed by Howitt (1995) because of increasing variable costs per unit of production due to inadequate machinery and management capacity, and due to decreasing yields related to land heterogeneity.

$$\max Z = \sum_i p_i x_i - d_i x_i - \tfrac{1}{2} x_i Q_{ii} x_i \quad (2)$$

$$Q_{ii} = \frac{1}{\rho_{ii}} * \frac{revenue^*}{x_i^*} \quad (3)$$

$$d_i = c_i - \lambda_i - Q_{ii} x_i^* \quad (4)$$

In Equation 2, parameter d_i denotes the vector of the linear term for crop and animal production activity i of the quadratic objective function, whilst Q_{ii} denotes the symmetric, positive (semi-) definite matrix of the quadratic cost term. Most PMP models estimate the matrix coefficients Q_{ii} and d_i of the quadratic cost terms based on exogenous supply elasticities ρ_{ii} from the literature, according to Equation 3. In Equation 3, the parameter *revenue** denotes the observed revenues from product sales in the base year and parameter x_i^* denotes the production levels of the base year. To determine the coefficients d_i and Q_{ii} (Equations 3 and 4), the shadow values λ_i of the calibration constraints for both marginal and preferential activities need to be recovered from the primal LP model described in Equation 1. In 'standard' PMP the cost functions are estimated for each production activity x_i separately, whilst Röhm *et al.* (2003) consider the elasticity of substitution among interrelated crops.

Because, in 'standard' PMP, increasing marginal costs are only assumed for preferential activities whilst constant costs are applied for marginal activities, PMP has often been criticised for its arbitrary assumptions (Howitt *et al.*, 2012; Kanellopoulos *et al.*, 2010). Thus, two PMP versions (Howitt *et al.*, 2012) have been developed to overcome these limitations. The first PMP version, the 'extended PMP variant', was published by Kanellopoulos *et al.* (2010). It solves this problem by estimating a Q matrix for either marginal or preferential activities by using exogenous land rents β in the linear objective function for the available area y according to Equation 5:

$$\max Z = \sum_i p_i x_i - c_i x_i - \beta * y \quad (5)$$

Another variant of PMP was proposed by Paris and Howitt (1998). This variant estimates the resource and calibration constraint shadow values based on maximum entropy (ME).

3. Methods and database

3.1 Overview of the agent-based sector model SWISSland

The agent-based SWISSland model depicts 3,400 farms from the Swiss Farm Accountancy Data Network [FADN] data pool as realistically as possible in terms of their operational and cost structures, as well as their social behaviour, as a representative sample of the estimated 50,000 family farms in Switzerland. The key objects of the model are agents representing FADN farms. For each farm, we model production and investment decisions, farm takeover and farm exit decisions, as well as lease decisions for land plots and inter-

Table 1. Behavioural and decision submodels included in the SWISSland agent-based sector model and data collection sources.

		Data Collection				Decision Model						
Submodels	Behaviour	Sample survey (FADN)	Sample survey (representative)	Census data	GIS data	Bayesian network	Microeconomic	Heuristic rule-based	Space theory-based	Institution-based	Preference-based	Hypothetical rules
Agent rational decision module	Production decisions	x					x					
Farm manager's life cycle	Farm takeover, Farm exit		x					x			x	
Land market	Lease decisions for land plots			x	x		x	x	x			x
Growth and investment	Investment decisions	x					x					
	Strategy for shifts in labour input	x				x	x	x			x	

action among agents on the land market (Table 1, categorised according to An [2012]). Table 1 also lists the various data sources and the methods we use for modelling the decision-making of the agents.

For the modelling of lease decisions, a spatial structure of representative reference municipalities was implemented in the model (Mack *et al.*, 2013). This allows the farms to interact on the land market. These interactions are only possible within the lease regions and with (constructed) neighbouring agents, however. A lease algorithm enables the plot-by-plot allocation of exiting farms' land to the remaining farms operating in the immediate vicinity. A plot-by-plot bidding process models which neighbouring agent receives the freed-up land and at what lease price. The neighbouring agent achieving the highest expected increase in income with the lease of the plot receives the lease plot.

Exiting farms are those where the farm manager is not passing on the farm to a successor, or where the potential successor decides against farm takeover on economic grounds. Two income parameters, (1) household income per farm and (2) agricultural income per total labour input, were selected to model farm takeover decisions. Income criteria to model farm exits and farm entries were derived from the regional income levels in the previous period from 2005 to 2012.

A detailed description of the different modules of the SWISSland model can be found in Möhring *et al.* (2016). Because this paper focuses on the modelling of production and investment decisions, we present this issue in detail in Section 3.2.

The model simulates a forecast period of up to thirty calendar years, corresponding more or less to a generational cycle of the farming family. The adaptive reactions of the individual agents and their behaviour when interacting with other agents are depicted in annual steps.

SWISSland calculates sectoral output indicators via an extrapolation algorithm. Zimmermann *et al.* (2015) have compared various extrapolation alternatives for the model. Product quantities and prices, land-use and labour trends, income trends according to the Economic Accounts for Agriculture, sectoral input and output factors for calculating environmental impacts, and key structural figures, such as number of farms, size and type of farm or number of farms changing their farming system, are all sectoral output indicators.

3.2 Options for modelling production and investment decisions

Rational agent behaviour is taken as an important basic assumption of the model. Hence, each agent maximises its annual household income for each time period t (Equation 6).

In keeping with the theory of adaptive expectations, the agents (a) make their production decisions based on price (p) and yield (ε) expectations from the previous year (t-1) for the various animal (l) and crop production (g) activities. Prices and yields were estimated for each agent on an individual-farm basis using the FADN data for the base year, with the observed price trends and average annual yield changes (Δ) resulting from 2000 to 2012 being stipulated exogenously for each time period.

Household income results from the sale of agricultural products originating from land use (*LAND g*) and livestock farming (*ANIMAL l*), from off-farm work (*OFFFARM o*), and from the proceeds of direct payments (*PAYMENT d*) less the means-of-production costs (*COSTFUNCTION*). The level of direct payments corresponds to the year-specific, production-dependent and production-independent approaches in each case, in accordance with current agricultural-policy provisions. Because this study tests various linear and PMP-based quadratic cost functions for crop and animal production activities, the cost functions are described in detail in the Equations 7-12 below.

$$Max\ INCOME_{a,t} = \Sigma_g p_{a,g} * \Delta p_{t\text{-}1,g} * \varepsilon_{a,g} * \Delta\varepsilon_{t\text{-}1,g} * LAND_{a,t,g} + \Sigma_l p_{a,l} * \Delta p_{t\text{-}1,l} * \varepsilon_{a,l} * \Delta\varepsilon_{t\text{-}1,l} * ANIMAL_{a,t,l} + \Sigma_o p_{a,o} * \Delta p_{t\text{-}1,o} * OFFFARM_{a,t,o} + \Sigma_d p_{d,a} * \Delta p_{t,d} * PAYMENT_{a,t,d} - OSTFUNCTION_{a,t}$$

subject to

$$\Sigma_g \omega_{a,g,w}^{LAND} * LAND_{a,t,g} \leq Area_{a,t}$$

$$\Sigma_l \omega_{a,l,w}^{\mathrm{ANIMAL}} * ANIMAL_{a,t,l} \leq Places_{a,t}$$

$$\Sigma_f \omega_{a,f,w}^{\mathrm{LABOUR}} * LABOUR_{a,t,f} * LAND_{a,t,g} + LABOUR_{a,t,f} * ANIMAL_{a,t,l} \leq LABOURCAP_{a,t} \qquad (6)$$

The resource endowment (ω) of a farm consists of the available area (*Area*), animal places on the farm (*Places*), other capacities limiting animal and crop production (e.g. sugar beet quota, milk quota up to 2007, provisions on the receipt of direct payments), and labour force (*LABOURCAP*).

The use of individual-farm FADN data ensures that various factors influencing the objective-function and production-coefficient matrix are automatically taken into account, allowing the depiction of numerous management options that are typical for Switzerland. The cost and output parameters of the production activities are therefore heterogeneous and influence the agents' decision-making scope.

Five different options for modelling animal and crop production decisions were analysed in this study (Table 2). Option 1 determines both crop and animal production decisions based on linear cost functions for 17 crops and 8 animal production activities according to Equation 7:

$$Max\ INCOME_{a,t} = REVENUE_{a,t} - \Sigma_l c_{l,a} * \Delta c_{t-1,l} * ANIMAL_{a,t,l} - \Sigma_g c_{g,a} * \Delta c_{t-1,g} * LAND_{a,t,g} \quad (7)$$

Option 1 does not calibrate the production activities to base-year levels. It takes into account the uptake of crop production activities which were not observed in the base year, but which occur in the farm's historic crop mix. For animal production activities, it considers the adoption of new production sectors. For modelling new production activities, which were not observed in the base-year, missing information must be added with the help of average values for other farms, or extrapolated using standard data. For all agent activities occurring in the production programme of the forecast years rather than in the base year, the yield and price coefficients are estimated with the aid of a random distribution based on the means and standard deviations of the values for all agents from the same region and farm type (see Möhring *et al.* [2016]).

Options 2a and 2b apply linear cost functions for animal production activities only, while PMP-based quadratic cost functions are used to determine crop production decisions (Equation 8). These options consider only crop production activities which were observed in the base year, whereas, for animal production activities, investment activities in new production sectors are taken into account.

$$Max\ INCOME_{a,t} = REVENUE_{a,t} - \Sigma_g c_{g,a} * \Delta c_{t-1,g} * LAND_{a,t,g} - \Sigma_g d_{a,g} * LAND_{a,t,g} - 0.5\ \Sigma_g Q_{a,g} * LAND^2_{a,t,g} - \Sigma_l c_{l,a} * \Delta c_{t-1,l} * ANIMAL_{a,t,l} \quad (8)$$

Option 2a estimates the matrix coefficients Q of the non-linear cost term based on base-year revenues (*revenue**) and base-year crop production levels (*LAND**), and uses supply elasticities equal to one owing to the lack of empirical data (Equation 9).

$$Q_{g,a} = \frac{revenue^*_{g,a}}{LAND^*_{g,a}} \quad (9)$$

For those production activities where the output is used on the farm itself, is calculated based on linear costs and shadow values according to the German farm type model FARMIS (Schader, 2009):

$$Q_{g,a} = (c_{g,a} + \lambda_{g,a}) / LAND^*_{g,a} \quad (10)$$

The linear term d of the quadratic cost function is calculated according to Equation 11.

$$d_{g,a} = \lambda_{g,a} - Q_{g,a}\,LAND^*_{g,a} \quad (11)$$

Option 2b estimates the matrix coefficients of the quadratic cost functions for crop production activities on the basis of maximum entropy. The maximum entropy technique in combination with the PMP calibration allows us to recover a quadratic activity variable cost function accommodating complementarity and substitution relations between activities. To estimate the parameter vector $d_{g,a}$ and the matrix $Q_{g,a}$ of the variable cost support points for the parameters were defined. As a starting point, the linear parameters $d_{g,a}$ could be centred around the observed accounting cost per unit of the activity. For example, the two unknown parameters are specified as an additive function of a number of support points. We could choose five support points Zd (d_1,..d_5) and ZQ (*zq1*,.. *zq5*) for parameter $d_{g,a}$ and the matrix $Q_{g,a}$. The entropy problem is maximised using support-points consisting of a Zd vector and a ZQ matrix. Because no cross cost effects are expected between crop and animal activities, the linear vector d of the quadratic activity cost function is partitioned into one vector which includes the crop activities and a second vector which includes the animal activities. Similarly, the quadratic matrix Q is partitioned into one matrix which includes the crop activities and a second matrix which includes the animal activities. Both PMP approaches guarantee exact calibration of supply decisions at farm and aggregated levels, taking into account the trade of factors among farms. Nevertheless, different approaches can produce different results when used to predict the future behaviour of the farmer.

Options 2a and 2b combine the advantages of both PMP and LP modelling, with PMP calibrating crop production activities to observed base-year levels taking into account the pedoclimatic conditions of the individual farms, and LP enabling modelling of the adoption of new animal production sectors. In all models with a linear cost function in animal husbandry, agents can invest in new barns, allowing them to expand their herd size considerably even within a specific time period, provided that all other necessary resources are available in sufficient quantity. Moreover, switching to new production activities is easily possible in the animal husbandry sector. In order to avoid an objective function with an integer formulation, however, individual barn construction variants (previously selected and evaluated according to plausibility) are tested iteratively with the aid of the loop process for each agent entitled to investment. Here, the annual external costs of the entire building (depreciation, repair, insurance and interest) are taken into account, irrespective of whether the barn can be fully utilised. If the agent is entitled to receive investment credits or investment aid, these lower the interest charges. Ultimately, the variant with the highest positive objective-function value is implemented. In the following year, all animal places resulting from the investment in the barn are available to the farmer. In this case, further use of the old barn is ruled out. Investment activities in new animal sectors are taken into account when a farm successor takes over from his predecessor. Only for older agents it was assumed that investment was primarily in the animal sectors pursued to date.

Options 3a and 3b test PMP-based quadratic production-cost functions for both animal and crop production activities (Equation 12):

$$Max\ INCOME_{a,t} = REVENUE_{a,t} - \Sigma_g c_{g,a} * \Delta c_{t-1,g} * LAND_{a,t,g} - \Sigma_g d_{a,g} * LAND_{a,t,g} - 0.5\ \Sigma_g Q_{a,g} * LAND^2_{a,t,g} - \Sigma_l c_{l,a} * \Delta c_{t-1,l} * ANIMAL_{a,t,l} - \Sigma_l d_{a,l} * ANIMAL_{a,t,l} - 0.5\ \Sigma_l Q_{a,l} * ANIMAL^2_{a,t,l} \quad (12)$$

Because investments in new barns radically alter the cost structure, the PMP-based cost function completely changes the function values derived in the base year. Since no methods were previously available to estimate the change in the PMP-based cost functions derived from the base year, a continuous model approach in which the agents continuously expand their barns by individual animal places was chosen for Options 3a and 3b.

Table 2. Modelling options for determining production and investment decisions in the farm-level models of the SWISSland agent-based sector model.

Option No	Name	Cost function for crop production activities	Cost function for animal production activities	PMP calibration method	Estimate of matrix coefficients of quadratic cost function	Investments
1	Linear	Linear	Linear	-	-	Investment activities for new buildings
2a	Linear-Quad-Revenues	PMP-based quadratic	Linear	Extended	Revenues	Investment activities for new buildings
2b	Linear-Quad-Entropy	PMP-based quadratic	Linear	Extended	Maximum entropy	Investment activities for new buildings
3a	Quad- Revenues	PMP-based quadratic	PMP-based quadratic	Extended	Revenues	Continuous investment costs for buildings
3b	Quad-Entropy	PMP-based quadratic	PMP-based quadratic	Extended	Maximum entropy	Continuous investment costs for buildings

PMP: Positive Mathematical Programming

3.3 Assessing forecasting performance

In this study, we assess the forecasting performance of the options based on the average forecasting error (AFE) measuring the difference between forecasted and historical parameters at the farm and sectoral scales. The farm-scale parameters assess the forecasting performance only of those agents who remained in the sample for the entire simulation period (2005 to 2012). In contrast, sectoral parameters represent changes in the total Swiss farm population over the period from 2005 to 2012 and take into account the farm sample changes due to farm exits and entries. Therefore, the simulation results from all agents were extrapolated to the sectoral scale based on Zimmermann *et al.* (2015).

At the farm scale, the AFE measures the percentage difference between historical and forecasted average production levels for each activity. The weighted average forecasting error (WAFE) of crops aggregates the AFE of all crops based on average production share in the FADN farm sample. The WAFE is calculated analogously for animals. Finally, the total weighted average annual forecasting error (TWAFE) aggregates the WAFE for crops and animals equally. At the farm scale, average crop and animal production levels from all FADN farms over a period of three years represent historical parameters.

At the sectoral scale, we calculate the production changes from 2003-2005 and 2010-2012 in percent. The forecasting error measures the deviation from historical values. At sectoral scale, historical values are based on production changes in the total Swiss farm population over this period.

4. Results

The SWISSland results were obtained for each specification rule of the cost function. Table 3 presents the historical average production levels of the corresponding FADN-farms and the AFE for crop and animal production activities in the short and long term. Linear cost functions for both crop and animal production activities (Option 1) lead at farm scale to the WAFE of almost 50% for crops and to the TWAFE for both animal and crop production in both time periods (Table 3). The results in Table 3 also show that crop activities supported by direct payments, such as extensive grassland, fallow land, oilseed rape, soya and sunflower, are highly overestimated in the linear version (Option 1), whilst PMP for crop production activities significantly reduces the AFE in both time periods. In the short term, the approaches with quadratic production costs for crop activities and linear production costs for animal activities (Options 2a and 2b) show, on average, the same WAFE as Options 3a and 3b with quadratic production costs for both animal and crop production activities. However, in the long term, Options 2a and 2b show better forecasting performance than Options 3a and 3b. The forecasting performance of Options 2a and 2b improves, in particular, for the livestock categories of cattle, dairy cows, suckler cows, horses and hens, which showed above-average production increases from 2005 to 2012 due to investment activities. Furthermore, the AFE of fodder and grassland activities decreases in Options 2a and 2b because these activities are highly influenced by the cattle production level. Only for marginal animal activities, such as sheep and goats, which are underrepresented in the Swiss FADN farm sample, is the AFE higher in the linear version than in the PMP variants. For crop activities as a whole, the entropy versions and the revenue versions lead to similar results in the short and long term. The results also show that both PMP variants (based on revenues or entropy) do not influence forecasting performance where PMP is combined with LP. Where PMP is used for both production categories, the entropy method leads to slightly better forecasting performance in the long term.

Table 4 shows that all model options using PMP (Options 2a to 3b) reproduce the observed farm exits in the long term much better than the linear version (Option 1), which significantly underestimates farm exits. Because high farm income reduces the probability of a farm exit, these results indicate that the linear version (Option 1) significantly overestimates farm specialisation and farm income. Comparing the extrapolated production changes of all agents with the historical production changes in the agricultural sector shows that the options with linear cost functions for animals (Options 2a and 2b) lead to better results in the long term, particularly in the sectors where the highest production increases were previously observed, such as suckler cows, hens, horses, goats and poultry. In these animal sectors, above-average investments in new housing, which overcompensate for the reduced production owing to farm exits, were observed in the past.

Table 3. Short- and long-term results at farm scale: Historical crop and animal production levels of all Swiss FADN farms and forecasting errors of the modelling options.

	Historical parameters Average production levels of all FADN farms			Average forecasting error of modelling options [AFE in %]									
	2003-2005	2006-2008	2010-2012	No 1 Linear[§]		No 2a Linear-Quad-Revenues[‡]		No 2b Linear-Quad-Entropy[†]		No 3a Quad-Revenues[¶]		No 3b Quad-Entropy[¤]	
	Base year	S	L	S	L	S	L	S	L	S	L	S	L
UNIT	(ha)	(ha)	(ha)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Bread grain	1.39	1.40	1.46	50	52	10	13	8	12	8	10	6	10
Feed grain	1.07	1.13	0.92	84	80	14	5	14	6	12	12	9	12
Grain maize	0.22	0.20	0.21	28	21	8	2	8	2	4	6	11	4
Silage maize	0.88	0.91	1.00	9	17	7	3	7	3	2	6	3	6
Sugar beet	0.30	0.32	0.32	11	12	3	4	3	4	2	3	3	3
Potatoes	0.30	0.27	0.25	299	326	2	4	2	5	13	8	3	9
Oilseed rape	0.21	0.23	0.30	237	162	14	34	14	33	12	33	12	32
Sunflower	0.04	0.05	0.04	321	444	11	15	11	15	15	15	11	15
Legumes	0.07	0.08	0.05	130	236	19	18	18	19	12	24	15	24
Vegetables	0.09	0.10	0.11	237	224	13	16	13	16	11	15	12	15
Fallow land	0.04	0.05	0.03	73	148	13	25	15	23	2	29	14	24
Temporary grassland	2.86	2.92	3.34	10	22	5	8	3	10	1	11	0	13
Extensive grassland	1.30	1.30	1.31	68	64	1	1	3	5	20	1	3	5
Less-intens. grassland	0.69	0.68	0.65	8	13	16	21	17	23	2	25	18	24
Intensive grassland	8.66	8.79	8.92	9	11	1	2	0	2	14	3	1	2
Extensive pastures	0.21	0.25	0.25	20	21	11	13	7	9	3	16	8	9
Intensive pastures	1.77	1.78	1.69	2	3	2	3	5	0	3	2	6	1
UNIT	(LU)	(LU)	(LU)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Livestock (total)	26.98	27.65	29.83	10	13	5	5	4	6	5	11	5	13
Cattle (total)	21.60	22.07	24.00	13	16	7	8	6	8	7	14	8	14
Dairy cows	14.80	14.97	16.21	11	15	6	6	3	6	4	11	4	11
Suckler cows	1.28	1.57	1.86	15	5	1	2	7	5	22	34	22	35
Horses	0.19	0.22	0.20	16	2	1	11	10	2	6	27	4	34
Sheep	0.21	0.22	0.22	14	33	29	33	14	30	4	7	3	8
Goats	0.05	0.05	0.06	8	6	11	10	7	11	5	23	2	23
Sows	3.98	4.14	4.08	5	7	9	10	7	10	6	9	5	7
Fattening pigs	2.52	2.61	2.67	7	1	2	4	8	3	14	13	14	2
Hens	0.34	0.35	0.59	1	25	19	18	0	21	1	40	3	39
Poultry	0.60	0.60	0.67	1	11	13	23	6	12	0	10	0	12

	Historical parameters Average production levels of all FADN farms			Average forecasting error of modelling options [AFE in %]									
	2003-2005	2006-2008	2010-2012	No 1 Linear[§]		No 2a Linear-Quad-Revenues[‡]		No 2b Linear-Quad-Entropy[†]		No 3a Quad-Revenues[¶]		No 3b Quad-Entropy[¤]	
	Base year	S	L	S	L	S	L	S	L	S	L	S	L
				Weighted average forecasting error [WAFE in %]									
Crop production				50	55	4	5	4	5	4	7	4	7
Animal production				10	14	6	10	6	10	7	13	7	11
				Total weighted average forecasting error [TWAFE in %]									
Average				30	34	5	8	5	8	5	10	5	9

S = Short term; L = long term; LU: Livestock Unit; FADN: Swiss Farm Accountancy Data Network Data Pool;
[§] Linear = Linear cost functions for crop and animal production activities;
[‡] Linear-Quad-Revenues = Linear cost functions for animal production activities and PMP-based quadratic cost functions for crop production activities. Estimate of PMP coefficients based on revenues;
[†] Linear-Quad-Entropy = Linear cost functions for animal production activities and PMP-based quadratic cost functions for crop production activities. Estimate of PMP coefficients based on maximum entropy;
[¶] Quad-Revenues = PMP-based quadratic cost functions for animal and crop production activities. Estimate of PMP coefficients based on revenues;
[¤] Quad-Entropy = PMP-based quadratic cost functions for animal and crop production activities. Estimate of PMP coefficients based on maximum entropy.

The results show that modelling investment decisions in new animal capacities based on linear cost functions (Options 2a and 2b) leads to better results than using continuous investment activities combined with quadratic cost functions (Options 3a and 3b). The results also show that PMP used for crop production activities underestimates production increases which are above-average (such as rapeseed, sugar beet, field vegetables etc.). These results are caused by two characteristics of PMP. On the one hand, the farm-level models only take into account the activities observed during the 2005 reference period, so the adoption of new crop production activities in subsequent years could not be taken into account. On the other hand, the quadratic cost functions prevent overspecialisation and above-average production increases for single activities. We can only assess the performance of the model based on its forecasting capacity.

5. Conclusions

This ex-post validation at farm scale clearly shows that, in the short term, supply curve specifications based on PMP only or on PMP combined with LP for selected

Table 4. Long-term results at sectoral scale: Historical sectoral production changes from base year 2003/05 to 2010/12 and deviation of model results from historical sectoral changes (+/- %) of the modelling options.

	Unit	Observed sectoral change from 2003/05 - 2010/12	No 1 Linear[§]	No 2a Linear-Quad-Revenues[‡]	No 2b Linear-Quad-Entropy[†]	No 3a Quad-Revenues[¶]	No 3b Quad-Entropy[¤]
		Historical change (+/-%)	Deviation from historical sectoral change (+/-%) of the modelling options				
Farm exits							
Total farms	Qty.	-11%	5%	1%	0%	2%	3%
Valley region	Qty.	-12%	5%	4%	2%	4%	6%
Hill region	Qty.	-9%	4%	-3%	-4%	0%	-1%
Mountain region	Qty.	-10%	3%	1%	1%	1%	1%
Farm size < 20 ha	Qty.	-18%	0%	-3%	1%	-1%	6%
Farm size 20-30 ha	Qty.	+4	8%	8%	-4%	6%	-2%
Farm size > 30 ha	Qty.	+15%	9%	-4%	-13%	-4%	-19%
Crop production							
Bread grain	ha	-4%	-17%	-11%	-14%	-1%	-3%
Fodder crop	ha	-17%	-36%	-2%	-5%	12%	9%
Potatoes	ha	-17%	28%	-7%	-7%	-1%	1%
Rapeseed	ha	35%	-52%	-48%	-50%	-41%	-43%
Sunflower	ha	-32%	23%	12%	12%	18%	15%
Field vegetables	ha	11%	173%	-14%	-17%	-9%	-10%
Silage maize	ha	12%	2%	-6%	-5%	-14%	-6%
Sugar beet	ha	6%	-23%	-12%	-12%	-11%	-7%
Open arable land	ha	-6%	8%	-6%	-8%	0%	1%
Temporary ley	ha	9%	2%	-3%	-7%	-15%	-13%
Total arable area	ha	-2%	5%	-4%	-7%	-4%	-3%
Permanent grassland	ha	-2%	5%	2%	-2%	3%	-2%
Total utilised agricultural area	ha	-2%	5%	0%	-3%	1%	-2%
Total livestock	LU	3%	1%	-3%	-5%	-9%	-11%
Dairy cows	LU	-6%	4%	2%	1%	-3%	-2%
Suckler cows	LU	55%	-6%	-17%	-20%	-60%	-60%
Pigs	LU	-3%	-1%	-6%	-6%	-3%	-34%
Fattening calves	LU	-13%	2%	1%	2%	12%	24%
Fattening bulls	LU	-6%	14%	5%	2%	2%	2%
Cattle total	LU	2%	0%	-4%	-4%	-11%	-9%
Sheep	LU	-1%	-19%	-21%	-21%	-5%	-3%
Goats	LU	25%	78%	78%	78%	-39%	-42%
Horses	LU	13%	93%	81%	-11%	88%	122%
Broilers	LU	31%	18%	13%	8%	-38%	-40%
Hens	LU	19%	10%	5%	2%	-20%	-20%

	Unit	Observed sectoral change from 2003/05 - 2010/12	No 1 Linear[§]	No 2a Linear-Quad-Revenues[‡]	No 2b Linear-Quad-Entropy[†]	No 3a Quad-Revenues[¶]	No 3b Quad-Entropy[¤]
		Historical change (+/-%)	Deviation from historical sectoral change (+/-%) of the modelling options				
			Average of absolute deviation from historical sectoral change (%)				
All attributes			20%	12%	10%	13%	16%

LU: Livestock Unit; [§] Linear = Linear cost functions for crop and animal production activities;
[‡] Linear-Quad-Revenues = Linear cost functions for animal production activities and PMP-based quadratic cost functions for crop production activities. Estimate of PMP coefficients based on revenues;
[†] Linear-Quad-Entropy = Linear cost functions for animal production activities and PMP-based quadratic cost functions for crop production activities. Estimate of PMP coefficients based on maximum entropy;
[¶] Quad-Revenues = PMP-based quadratic cost functions for animal and crop production activities. Estimate of PMP coefficients based on revenues;
[¤] Quad-Entropy = PMP-based quadratic cost functions for animal and crop production activities. Estimate of PMP coefficients based on maximum entropy.

production activities significantly improve the forecasting performance of an agent-based model compared with specifications based on LP only. For short-term forecasts, where investment decisions do not play a major role, PMP for all production activities and PMP combined with LP produce similar results. For long-term forecasts, the results at farm scale and at sectoral scale show that combining LP for animal production activities with PMP for crop production activities leads to the best forecasting performance. The combined approach could mitigate some limitations of PMP which are relevant mainly in the medium and long term, such as the adoption of new production activities, while still exploiting the advantages of PMP in order to avoid overspecialised model results.

This study confirms also the finding of Buysse *et al.* (2007) that, in sectors where new production activities are expected to be adopted owing to market and policy changes (i.e. switching from direct payments towards market support or opening borders of an isolated country), the LP approach could represent an appropriate solution, in particular in long-term forecasts, whereas, in the case of minor policy changes or in the short term (i.e. slight modifications of direct payments or tariffs), PMP could improve the forecasting results. The underlying reason for this might lie in the fact that farmers have to take both gradual and binary decisions. In animal production, either a new house will be built or it will not. After a radical reform of agricultural policy, the farming business will be continued or not. Our results have shown that, for such binary decisions, LP is effective. For situations where price fluctuations suggest an increase in potatoes at the expense of a farmer's wheat acreage, PMP is a more suitable instrument.

The results show that supply curve specifications based on the extended variant of PMP and that revenues and specifications based on PMP and maximum entropy lead to similar results. The results support other studies by Gocht (2005) and Winter (2005), both of whom discovered that the different PMP versions led to similar model results. Although all tested approaches lead to deviations in the actual observable trends, we may conclude that PMP for crop production activities combined with LP for animal production activities is preferable to full PMP when assessing the forecasting performance of sectoral production changes in the medium or long term.

At the same time, this paper shows that, in general, an ex-post validation makes a valuable contribution to improving the accuracy of the model, but can also make a theoretical contribution to the methods used. On the other hand, this example demonstrates that PMP and LP approaches have their strengths and weaknesses in individual areas. For this reason, the methodological considerations for improving mathematical programming should be continued. This will not only improve the predictive accuracy of the model results, but, just as importantly, it will also have positive consequences for the acceptance of model simulations for use in policy advice.

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Full Research Article

The impact of assistance on poverty and food security in a fragile and protracted-crisis context: the case of West Bank and Gaza Strip

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Abstract. This paper assesses the impact of assistance on the wellbeing of Palestinian households. The impact evaluation analysis uses a difference-in-difference approach for the treatment of sample selection bias. The paper uses data from the 2013 and 2014 rounds of the Palestinian Socio-Economic and Food Security survey to estimate the impact of assistance to West Bank and Gaza Strip (WBGS) households on their poverty and food security status. Results suggest that both poverty and food insecurity would have been much higher for WBGS as a whole without assistance, further increasing in areas with lower levels of assistance. However, the average positive impact of assistance hides a lot of heterogeneity. In fact, while there is a clear positive impact of the intensity of assistance on poverty reduction, food consumption and diet diversity in the West Bank, Gaza Strip analysis shows mixed results. Results highlight how the international community cannot disengage from supporting Palestinian households without severely impacting their wellbeing.

Keywords. Poverty, food security, impact analysis, West Bank and Gaza Strip.

JEL codes. Q18, I32.

1. Introduction

The relationship between foreign assistance[2] and development is one of the most debated topics in development policy. Since World War II, the debate shifted from discussing the rationale for mobilizing foreign resources to boost economic growth (Chenery and Bruno, 1962; Chenery and Strout, 1966; Lal, 1972), to assessing the impact of aid on

[1] The views expressed in this paper are those of the author(s) and do not necessarily reflect the views of the Food and Agriculture Organization of the United Nations.
[2] Foreign assistance is a broad term for any voluntary transfer of resources from one government, international organization, or NGO to a recipient country, usually a developing country. It encompasses loans (both soft or hard) and grants as well as in-kind transfers and technical assistance. The paper uses "foreign assistance" interchangeably with the term "foreign aid".

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economic growth and poverty reduction (Bauer and Yamey, 1982; Cassens & Ass., 1986; Krueger, 1986; Mosley, 1987; Collier and Dollar, 2001 and 2002), and subsequently to generating evidence in order to better design interventions and enhance aid effectiveness (Burnside and Dollar, 2000; Hansen and Tarp, 2001).

More recently, increasing attention has been devoted to assessing the effectiveness of assistance delivered in fragile contexts.[3] This shift was driven by empirical evidence suggesting that natural, economic and political risks are rising across the world (World Bank, 2011; Zseleczky and Yosef, 2014), as well as by the rapidly growing literature on fragile states (Ipke, 2007; Kaplan, 2008; Zoellick, 2008; Baliamoune-Lutz and McGillivray, 2008; Stewart and Brown, 2009; Andrimihaja *et al.*, 2011; Chandy, 2011; Naudé *et al.*, 2011). The key question here is whether aid can deliver its expected results within fragile/conflict contexts. The literature shows mixed empirical evidence (Dollar and Levin, 2006; Fielding and Mavrotas, 2008; Ishihara, 2012; Chandy *et al.*, 2016). As a result, many practitioners, policymakers, and even laypeople express mounting concern for the poor development records within fragile country contexts. This implies a need to develop new approaches that explicitly address fragility pathways to insecurity when designing development and humanitarian assistance strategies in fragile/conflict contexts (OECD, 2007; EU Commission, 2009; World Bank, 2011).[4]

This paper contributes to the empirical literature on the impact of assistance in fragile contexts by adopting a microeconomic perspective. It aims to estimate the impact of assistance intensity on household wellbeing proxied by two outcome dimensions, poverty and food security. We adopt a counterfactual framework using a difference-in-difference approach to address sample selection bias as well as instrument variable econometric modeling to get rid of endogeneity problems where appropriate (e.g. poverty reduction).

The empirical application focuses on the specific fragile, protracted-crisis context of the West Bank and Gaza Strip (WBGS) as a case study. This specific region was chosen for several reasons. WBGS has been among the highest per-capita recipient of official development assistance worldwide (World Bank, 2019) and it is also experiencing one of the longest contemporary conflict in the world. The majority of Palestinians living under occupation would be unable to meet their own bare necessities since both humanitarian and development interventions in WBGS are largely financed by foreign assistance. Indeed, the pledge for humanitarian assistance, amounting to USD 540 million in 2018 (OCHA, 2017a), is completely financed by foreign resources. Similarly, the share of for-

[3] There is no universally accepted definition of fragility. Instead of trying to stringently define fragility, OECD (2015) identifies fragile contexts according to a multi-dimensional framework that helps reveal different patterns of vulnerability in a given country. The five fragility "clusters" considered by OECD are the following: widespread violence, limited justice, ineffective and unaccountable institutions, weak economic foundations, and low resilience to shocks and stressors. These characteristics substantially impair the fragile country's economic performance, the delivery of basic social services, and the efficacy of donor assistance.

[4] This was explicitly considered by the so-called "New Deal for Engagement in Fragile States" announced at Busan in 2011. This deal identified five "Peace-building and State-building Goals": legitimate politics, security, justice, economic foundations, and revenues and services (https://www.pbsbdialogue.org/en/). It also considered in the United Nation's "New Way of Working", (https://www.un.org/jsc/content/new-way-working) within which humanitarian, development and peace actors are called to work together to pursue collective outcomes over multiple years to overcome the traditional divide between humanitarian and development interventions. This is at the core of the so-called "Triple nexus", which aims to integrate the humanitarian, development and peace aspects of interventions.

eign support in 2018 accounted for as much as 48% of total development expenditure, a sum roughly equal to USD 381 million (IMF, 2018).

Between 2007-2016, the yearly average total of aid received amounted to more than 2.3 billion USD per year or 23% of Palestinian GDP (WDI, 2018). Despite such large aid inflows, the Palestinian GNI per capita is still around USD 3,180 (WDI, 2018), qualifying WBGS as a lower-middle income country. Similarly, the Palestinian HDI is 0.686, placing WBGS 119th out of 189 countries and territories (UNDP, 2018). According to the humanitarian needs assessment (OCHA, 2018), some 2.5 million people are in need of assistance on a total population of 4.95 million and 1.9 million people are targeted by humanitarian interventions. In factIn light of this, data released by the Palestinian Central Bureau of Statistics (PCBS) regarding the 2013 and 2014 Socio-Economic and Food Security (SEF-Sec) survey data (FSS-PCBS, 2016) — designed for the first time as a panel — offers a unique opportunity to assess the impact of assistance on household poverty and food security in WBGS. It is important to note that from 2013 to 2014, the period in which the data was collected, the region faced persistent occupation as well as an open-arm conflict in the Gaza Strip occurring from July 2014 to August 2014.

To conduct the aforementioned analysis, the paper is organized in the following way: Section 2 reviews the literature on aid and development, looking at both theoretical arguments and empirical results. Section 3 introduces the Palestinian context and provides an overview of assistance to Palestinian households. Section 4 analyzes Palestinian households' profiles in terms of poverty and food security at the beginning of the period of analysis. Section 5 describes the data and methods used in the impact evaluation. Section 6 discusses the results of the impact evaluation analysis. Finally, Section 7 summarizes main findings and discusses policy implications.

2. Foreign Assistance and Development: An Introduction

Foreign assistance can be traced back to the colonial period. At the time, European powers provided large amounts of money to their colonies, typically to improve infrastructure, with the ultimate goal of increasing economic output. The use of foreign assistance as it is known today — as an instrument to help poor countries improve living standards — came into existence only after World War II (Thorbecke, 2000). The emergence of a new economic order and the founding of international organizations (such as the United Nations, the IMF, and the World Bank) following WWII shaped foreign aid to become what it is today. The success of the Marshall Plan, the US-sponsored package implemented between 1948 and 1953 to rehabilitate the economies of Western and Southern European countries, showed that capital transfers alongside technical assistance could effectively spur growth so that targeted economies were able to surpass their pre-war economic levels by 1952.

Aid to developing countries today is more complex. Its use is determined by several intertwined motives, including altruism, access to markets and resources, geopolitics, and colonial legacies. The impact of foreign assistance to developing countries is mixed, with success stories in various South East Asian countries but also numerous failures in Sub-Saharan countries (Kanbur, 2000).

Foreign aid is thought to have helped poor countries raise income per-capita growth rates, in some cases converging with high-income countries, successfully lifting large segments of the population out of poverty. However, this is difficult to establish unequivocally. There are two major difficulties when analyzing the relationship between foreign assistance and development. Firstly, there are issues with different theoretical frameworks–macro as well as micro–that provide the rationale for foreign aid interventions. Secondly, empirical studies lack conclusive evidence, making it hard to identify causal links between aid and development outcomes. Indeed, there is a large gap between aid achievements at the micro and macro levels, with greater difficulties in establishing causalities at the macro/country level compared to the micro/project level. This is the so-called "micro-macro paradox" (Mosley, 1987). As a consequence, the effectiveness of aid in the promotion of development is often uncertain and controversial, with personal opinions often deeply founded in ideology.

The consequence is an ongoing debate regarding best practices in the provision of foreign assistance aptly named the "aid debate".[5] Positions on the matter range from strong believers in the potential effectiveness of foreign aid who advocate for even more aid (Sachs, 2005), to deep skeptics stressing the importance of experimentation and learning from past mistakes (Easterly, 2006). Along this spectrum lie pragmatists who support peace and the use of a broad set of instruments (Collier, 2007) as well as opponents endorsing anti-corruption practices to increase aid effectiveness (Moyo, 2009). Finally, the aid debate also includes scholars who argue for the reduction of damaging OECD trade policies in agriculture, increased provision of technical assistance regarding institution building, an increase in investment devoted to fighting diseases and improving agricultural technology in tropical environments, and greater support for institutional reforms that favor secure property rights, the rule of law, and a reduction in arms sales to developing countries (Deaton, 2013).

2.1 Macroeconomic perspective

The most important theoretical arguments in support of foreign aid as an effective strategy to boost growth and catch-up to rich countries are rooted in Keynesian growth models. The Harrod-Domar model (Domar, 1957) provides theoretical background for growth in developing country contexts by identifying savings rate and choice of technique (via the incremental capital-output ratio, or ICOR) as the two determinants of a country's growth rate. The policy implications the model suggests for accelerating growth are clear: raise the savings rate (i.e. promote savings through stronger financial institutions) and lower the ICOR (i.e. increase the marginal productivity of capital through better technology). This is where foreign aid transfers come in. Using these transfers for investment can fill domestic saving gaps in developing countries, thus providing a "Big Push" to kick-off economic growth (Rosenstein-Rodan, 1943).

A popular extension of the Harrod-Domar model devised in the 1960s in Latin America defined two kinds of capital goods used in production. The first kind are capital goods of domestic origin, such as buildings financed by domestic savings, while the other

[5] Foreign aid has throughout its history been subjected to close scrutiny both by academic researchers and others (Dethier, 2008). A large literature extending over several decades bears witness to this, and the boundary between policy advocacy and research has not always been clearly delineated.

kind are of foreign origin, such as imported intermediate goods and machinery paid for using foreign savings. If the two forms of capital are in fixed proportion, then the scarcest of the two types of savings will always be binding. This is the core of the “two-gap model” (Chenery and Bruno, 1962; Chenery and Strout, 1966). Foreign aid that increases foreign savings can effectively increase growth with enough domestic savings, despite a deficit of foreign exchange. However, foreign aid cannot translate to growth if there is a deficit of domestic savings even if an economy has enough foreign exchange to acquire necessary amounts of imported capital goods.

Subsequent developments are based on new growth theory, which endogenously explains productivity growth by extending the above paradigm with an analytical basis for empirical cross-country studies (Robinson and Tarp, 2000). The underlying causal chain runs from aid to savings, from savings to investment, and finally from investment to growth. In the new growth theory approach, investment and productivity variables are assumed to depend on policy and institutional variables.

Usually, the effectiveness of aid has been empirically tested using country-level macro data, with aggregated aid as a single resource. Such tests examined whether more aid lead to better outcomes, in particular whether more aid lead to higher growth. It is no surprise that reduced-form analysis shows tenuous links between aid and development outcomes, since aid is often advanced for non-developmental objectives, such as disaster relief or military and political ends. As emphasized by Bourguignon and Sundberg (2007: 317) development economists must better understand “the links from aid to final outcomes” because “trying to relate donor inputs and development outcomes directly, as through some kind of black box, will most often lead nowhere.” Opening the black box allows for the identification of three types of links–from donors to policy-makers, from policy-makers to policies, and from policies to outcomes–which, in turn, may provide additional answers.

Empirical studies on the link from donors to policymakers reveal a body of circumstantial evidence built primarily on years of failed aid efforts (Dollar and Levin, 2006). Donor views regarding the “right development policies” have been promoted through aid conditionality with little attention to specific country contexts. For instance, public enterprise privatization and finance liberalization have at times been regarded as necessities, though were encouraged with little regards for local socioeconomic conditions, making such measures ineffective, risky, or simply counterproductive. The link from policymaking to policy formulation and implementation depends largely on governance systems. There is evidence suggesting the association between good governance and good policies, although the direction of causality is hard to determine. In practice, most research has focused on the relationship between governance and development outcomes, bypassing the impact on policies and pointing instead to the importance of good governance for better outcomes (Acemoglu *et al.*, 2005). Regarding the impact of policies on outcomes, there is a good understanding of the effect of macro stability, investment climate, as well as well-managed trade openness on growth, even though country specificity can make it hard to generalize the impact of these factors. Cross-country comparisons however indicate that better-quality policies are associated, on average, with higher GDP growth.

Some authors use empirical analyses to argue that aid leads to growth with decreasing returns (Hansen and Tarp 2001). Others suggest that national growth-inducing policies may reduce aid effectiveness because good policies and aid are substitutes of each other (Dalgaard and Hansen 2001). Finally, some authors hold that aid stimulates growth conditional on key features. For instance, it is often argued that aid works if provided to countries that implement good policies (Burnside and Dollar 2000). This conclusion was questioned by Easterly *et al.* (2004) who showed that the aid-policy relation was not robust enough for the expansion of the database in years and countries. Despite such differing positions, cross-country regression analysis largely concludes that the relationship between aid and development outcomes is weak and often ambiguous (Rajan and Subramanian, 2005; Clemens *et al.*, 2004).

In recent years, econometric assessments have included meta-analyses to synthesize results from the existing body of empirical data while controlling for heterogeneity among studies. Surprisingly, even these studies, which are supposed to provide more objective analyses, have contributed little to resolving the aforementioned controversies. Consider, for instance, two such studies by Doucouliagos and Paldman (2009) and Mekasha and Tarp (2013): while the former failed to find any significant impact of foreign aid on growth, the latter found an impact that is both positive and statistically significant.

In conclusion, macro growth effects are both harder to achieve and harder to observe. They are harder to achieve than micro growth effects because the magnitude of aid may not be sufficient to affect recipient countries' macro variables, and harder to observe because causality is difficult to establish in cross-country regressions (Mavrotas, 2015).

2.2 Microeconomic perspective

Non-conclusive results of reduced-form cross-country aid regressions brought about the need to establish the channels through which aid mattered the most for economic growth and poverty reduction (Dalgaard *et al.*, 2004). This was done through empirical studies at the micro level that analyzed the impact of single project and program interventions. Until the 1990s, these evaluations were based on cost-benefit analysis (CBA) of single projects by computating the internal rate of return of the intervention. Such studies show that aid is effective at the micro level when taking into considerations local projects (Hirschman, 1967; Mehrotra and Jolly, 1997). However, these results came under severe criticism once the concept of aid fungibility, i.e. aid money being used for purposes other than those earned, spread. In fact, rate-of-return metrics ignore more complex opportunity-cost issues like the fungible use of foreign aid. The approach also became problematic as donors started to embrace broader goals for aid, such as environmental sustainability and multiple social goals with hard-to-quantify objectives. In parallel, the weakness of CBA-based impact evaluations, summarized under headings such as "before-and-after" and "with-and-without," was the topic of many debates. Consequently, methodological issues became increasingly important in the aid-effectiveness debate (Cassen & Ass., 1987; World Bank, 1998).

More recently, knowledge at the micro and project level has expanded based on evaluations using advanced econometric techniques and rigorous experimental or quasi-experimental designs. Econometric techniques are used to examine the impact of specific policies or projects on local communities, household decision making, and individual welfare (Banerjee and Duflo, 2011). Given the number projects and their different impacts in varying country circumstances, continued evaluation and revision is needed. Impact evaluation evidence began in the mid-1990s. By the turn of the century, impact evaluation publications became increasingly more common, continuing to date (Cameron *et al.*, 2016).

Rigorous ex-post impact evaluations help inform government and donor decisions, an idea supported by donor agencies and even by aid critics (e.g., Easterly 2006). However, an evaluation gap still exists. This is because governments, official donors, and other funders do not demand or produce enough impact evaluations and those that are conducted are quite often methodologically flawed (Savedoff *et al.*, 2006). This calls for a systematic review of conclusions drawn from such studies. Several initiatives have been implemented in response to this issue, such that many reviews and meta-analyses are in circulation today. In terms of sectors, the ones most represented in studies are social protection, health and nutrition, and education. Cash transfers is the most represented modality, though in-kind transfers and vouchers are also well-researched, especially in the context of humanitarian crises. Randomized control trials and difference-in-difference studies are the most widely used methods.

Studies assessing the causal relationship between interventions and outcomes of humanitarian assistance generally lack a reliable and robust base of evidence (Clarke *et al.*, 2014). Only a small proportion of the many evaluations of humanitarian assistance use designs with a counterfactual, control or comparator group that allows the studies to attribute measurable changes outcome indicators to programs or policies. However, there are also several examples of randomized trials. It is possible to generate evidence for specific questions using randomized trials, although this evidence base is limited and concentrated in certain areas, such as mental health (Cameron *et al.*, 2015).

Foreign aid has generally brought about a positive contribution in education, the most tangible outcome being increased enrolment rates in primary education (Riddell and Niño-Zarazúa, 2016; Birchler and Michaelowa, 2016). However, there is a considerable gap regarding the contribution of aid to improvements in the quality of education. Masino and Niño-Zarazúa (2016) conducted a systematic review of experimental and quasi-experimental evidence to establish what works best to improve education quality in developing countries. They found that educational policies are most successful when implemented in combination with multiple interventions. Aid channeled into a variety of interventions, targeting different educational levels and utilizing different aid modalities works best. Considering this heterogeneity, it should not be surprising that a generalized blueprint applicable to all developing countries hasn't been devised.

Literature in the food security and nutrition sector has a lot of variation in program implementation (e.g. size and modality of transfers, duration and frequency of transfers, strength of conditions, pre-existing levels of undernutrition, health services). This makes difficult to establish which of the various interventions on food security and nutrition is most effective. Conclusions of summary studies range from cautiously optimistic (Ahmed *et al.*, 2009; Ruel *et al.*, 2013) to lacking significant results (Manley *et al.*, 2012). In 2016, Doocy and Tappis reviewed 108 studies on intervention modalities. They found that unconditional cash transfers and vouchers may improve household food security among conflict-affected populations and maintain household food security during crises specifically affecting food, such as droughts. Moreover, unconditional cash transfers led to greater improvements in dietary diversity and quality than food transfers. Food transfers were found to be more effective in increasing per capita caloric intake than unconditional cash transfers and vouchers. While the evidence reviewed offers some insights, the scarcity of rigorous research on cash-based approaches limits the strength of such findings.

However, drawing on findings from randomized control trials, Karlan and Appel (2012) identify seven ideas that work: microsavings; reminders to save; prepaid fertilizer sales; deworming; remedial education in small groups; chlorine dispensers for clean water; and commitment devices. Likewise, Banerjee and Duflo (2011) draw on experimental studies to identify a host of promising interventions in areas ranging from health and education to policing.

Though promising, impact evaluation studies have several limitations. It is illusory to believe that all interventions can be subject to impact evaluations and that such evaluations will permit the flow of aid exclusively to what works, as some have suggested (Easterly, 2006; Banerjee, 2007). It is impossible to evaluate all projects. Evaluations can also be misleading when projects or programs are applied outside the context in which they were evaluated, meaning there is a serious problem of external validity (Pritchett and Sandefur, 2013). Furthermore, many policies have general equilibrium effects often ignored by impact evaluations. This suggests that unlocking the secret of aid effectiveness is most likely to be revealed by trial and error than by randomized control trials (Deaton 2013). Nonetheless, experimental and quasi-experimental studies are grossly underutilized instruments with tremendous scope to improve and regularize their use in bilateral and multilateral donor agencies. A larger evidence base and a more standardized approach to documenting and comparing costs and benefits of interventions are needed to draw important conclusions on the effectiveness of different development interventions (Savedoff *et al.*, 2006; White, 2010; Cameron *et al.* 2016).

2.3 Aid effectiveness in fragile contexts

The new economics of aid stresses the importance of good governance to successfully achieve growth. Focusing on good governance leads to country selectivity such that transfers are targeted at countries that pass the good-policy test. This means aid is shifted from project financing to budget financing. However, targeting countries with high institutional and policy scores means that poor individuals in countries with failed states and in post-conflict societies will not be reached. The problem of building a developmental state that qualifies for aid is also left open. Social development funds, local governments, and NGOs therefore play an important role: they can bypass central governments while capacity building for improved governance goes on.

Traditional empirical research has largely dismissed the analysis of fragile or conflict contexts. For instance, econometric evidence used in the aid-effectiveness debate suggests that the ineffectiveness of aid is due to the failure of the recipient governments to create the right policy environment. However, this data uses a cross-section of countries without any specific focus on fragility contexts that, at best, were treated as a dummy variable in the regressions (Boone, 1995; Burnside and Dollar, 2000; Hansen and Tarp, 2001; Dalgaard and Hansen, 2001; Easterly *et al.*, 2004; Doucouliagos and Paldam, 2009). The same reduced-form approach based on country aggregate data has been adopted in more recent literature on the "growth-efficient" level of aid.[6] The literature found that the relationship between aid and growth takes on an inverted-U shape for both fragile and non-fragile countries, identifying a lower growth-efficient level of aid in the former as compared to the latter (Gomanee *et al.*, 2005; McGillivray *et al.*, 2006; McGillivray and Feeny, 2008; Feeny and McGillivray, 2009; Naudé *et al.*, 2011).

Existing evidence from impact evaluations in fragile contexts is equally poorly developed. A recent evidence gap map review of impact evaluations found little to no evidence on most categories related to the five Peace-building and State-building Goals. Only two Goals (community-driven reconstruction and psycho-social programs for victims) had a large enough number of studies to be promising for evidence synthesis. While prioritizing new research in understudied areas might help fill such knowledge gaps, the nature of experiments also imposes limits on what is studied. In addition to the common limitations of randomized studies (cf. section 2.2), some interventions may be impractical or unethical in fragile/conflict contexts (Humphreys, 2015). Some authors therefore look beyond the standard impact evaluation approach, choosing instead to focus on the drivers of success in fragile contexts by developing comprehensive theories that identify important factors and establish how they interact to create outcomes. The authors then test or demonstrate the plausibility of their arguments through case studies (cf., for example, Guisselquist, 2015).

Addison (2000) was one of the first in the field to discuss the role of aid before, during, and after armed conflicts. He found that aid distributed during conflicts plays a minor yet positive role in humanitarian assistance as well as in the transition from war to peace. There are, however, serious problems in operating in wartime environments. This author notes that aid can complicate conflicts when it falls into the hands of belligerents. After periods of war, aid plays a major role in rehabilitation and reconstruction efforts. Finally, Addison considers the possibility of using aid to prevent conflict in areas at risk, arguing that foreign policy support should incorporate aid in conflict prevention efforts. Such aid should focus on reducing poverty and inequality to dampen social tensions as well as support institutions and processes for conflict resolution.

More recently, Guisselquist (2015) argued that development assistance to fragile states and conflict areas can act as a core component of peacebuilding by providing support for the restoration of government functions, the delivery of basic services, the rule of law and economic revitalization. Significant gaps exist regarding what has worked, why it has worked and the transferability and scalability of such findings. Nevertheless, three broad factors can identify why some interventions work better than others. The first is the area of intervention and the related degree of engagement with local state institutions. The second factor relates to local contextual elements, including windows of opportunity, capacity and the existence of local supporters. Finally, the third set of factors deals with project or program design and management. While the third set of factors is largely transferrable and scalable, the first two are less so and should be considered carefully when assessing the feasibility of extending project or program models to new contexts. Area of intervention, degree of engagement with domestic institutions and local contextual elements are

[6] The so-called "growth-efficient" level of aid is the level of aid beyond which more aid is associated with lower growth.

vital factors to consider when making adjustments to improve the viability of development programs.

Finally, a more radical approach was proposed by authors adopting a political economy perspective to analyze the workings of aid in conflict contexts (Murshed, 2002; Sogge, 2002; Kanafani and Al-Botmeh, 2008; Hever, 2010; Taghdisi-Rad, 2011 and 2015). The authors argue that the debate on aid effectiveness in fragile contexts has treated conflict as an external factor to be considered only at a much later stage in the analysis. They believe that a conflict and its interaction with local socio-economic structures should instead be the starting point of the analysis. As Taghdisi-Rad (2015: 5) said, it is imperative to understand "the nature of [a] conflict and the ideological forces behind its continuation … to construct a framework for the analysis of economic performance under any given conflict".

3. Assistance to Palestinian Households

3.1 West Bank and Gaza Strip: a fragile and protracted crisis context

The world's longest on-going crisis is in the West Bank and Gaza Strip, marked by more than fifty years of occupation, repeated waves of violence, and wars. The last two decades of Palestinian history have been marked by the construction of a separation barrier, the closure of the Gaza Strip in 2007, three devastating conflicts in 2008/2009, 2012 and 2014 respectively, as well as the increasing territorial fragmentation resulting from the continued expansion of Israeli settlements in the West Bank. The hope for greater welfare and stable economic growth brought about by the Oslo Accords (1993-95) has withered as a result of the unresolved Israeli-Palestinian conflict.[7] Moreover, a growing political divide between the West Bank and Gaza Strip has further destabilized the economy.

The attainment of Palestinian economic development is largely dependent on economic relations with Israel. According to the Paris Protocol, the Palestinian economy works under the framework of a customs and monetary union with Israel (Hever, 2015; UNCTAD, 2015).[8] The Palestinian government cannot exert power over its borders nor

[7] The Oslo Peace Accords, under which the Palestinian Authority (PA) was created in 1994, were intended to lead to a final negotiated settlement between the parties. The accords led to several administrative and security arrangements for different parts of the West Bank, which became divided in Areas A, B and C, with the PA having civil and security authority only in Area A (which accounts for 18% of the West Bank) and no authority whatsoever in Jerusalem. These were meant to be provisional terms, pending a final negotiated settlement. Permanent issues such as the status of Jerusalem, security arrangements, international borders, and the rights of Palestine refugees (5 million Palestine refugees are to this day dispersed across the Middle East) were left to be resolved after a five year interim period that ended in 1999. Twenty-five years after the Oslo Accords, no progress has been made to settle the aforementioned pending issues (EU Commission, 2018).

[8] The Protocol on Economic Relations, also called the Paris Protocol, is an agreement between Israel and the Palestine Liberation Organization signed in April 1994. It was incorporated into the Oslo II Accord of September 1995 with minor emendations. Originally, the Paris Protocol was to remain in force for an interim period of five years, yet it is still being enforced today. Essentially, the Protocol integrated the Palestinian economy into the Israeli economy through a customs union where Israel controls both Israeli and Palestinian borders (Elkhafif *et al.*, 2014). The Protocol regulates the relationship and interaction between Israel and the Palestinian Authority in six major areas, namely: customs, taxes, labour, agriculture, industry and tourism.

does it have an independent monetary policy.[9] Economic growth suffers as a result of restrictions and controls placed on the movement of people and goods, access to resources such as land and water and access to productive inputs and markets. The Palestinian government has limited ability of collecting its own taxes, while Israel recurrently withholds revenues collected on behalf of the Palestinians. Consequently Palestinian public finances are seriously destabilized. The situation is further complicated by the internal political divide that further limits the sovereignty of the Palestinian government. In such a situation, the scope and geographical coverage of policy interventions has limited effectiveness.

As long as barriers to trade, access, and movement remain high, the Palestinian economy will continue on its current path of low growth.[10] The Palestinian economy grew on average 5.5% per year over the last decade, with a marked difference between the West Bank and Gaza Strip. The economy slowed down in the last few years, so much so that 2017 estimates project GDP to fall from 3.1% to 1.7% per year in the medium-run (IMF, 2018). This is mostly due to the reduction of donor flows and the possibility of running tensions increasing further. With an expected population growth as high as 2.8% in 2017, the aforementioned implies a stagnation, if not a contraction, of per-capita incomes. Unemployment continues to be high (27.8% in 2017) and labor force participation continues to be low, with structural unemployment particularly affecting young people and women: only 41% of youth between 15 and 29 years of age are active in the labor market while only 19% of women are active. Household and government consumption are the main drivers of economic activity. The two crowd out the investment necessary for faster growth. Primary capital inflows into Palestine are remittances and development assistance rather than FDI. Meanwhile, the national economy is highly import-dependent, Israel remaining by far its main trading partner.

Overall, the Palestinian economy is still highly aid-dependent despite a sharp decline in aid. UNCTAD (2018) found that international developmental support to Palestine in 2017 amounted to USD 720 million, only one third of the USD 2 billion received in in 2008. Over the same period, budget support shrank from USD 1.8 billion to USD 544 million, a 70% decrease.[11] Moreover, the fiscal burden of humanitarian crises and occupation-related fiscal losses have diverted donor aid from development to humanitarian interventions and budget support. As emphasized by UNCTAD (2015), no amount of aid would have been sufficient to put any economy on a path of sustainable development under conditions of frequent military escalations.

Poverty and low standards of living are increasing in Palestine. The poverty headcount ratio at the national poverty line was estimated to be 29.2% in 2017 (PCBS, 2018a), well above the 2011 poverty headcount ratio of 25.8%. The proportion of poor in 2017 stood at 13.9% in the West Bank and 53.0% in the Gaza Strip. In that year, about 16.8% of Palestinians lived in extreme poverty (almost four percentage points more than in 2011),

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[9] The agreement defined specific arrangements through which the Government of Israel collects VAT, import duties and other so-called clearance (custom) revenues on behalf of the PA, sharing it with the latter on a monthly basis. These revenues account for 73% of the PA's total net revenues (EU Commission, 2018).

[10] World Bank (2017) estimates indicate that removing Israeli restrictions could increase annual GDP growth up to 10%.

[11] The recent decision made by the United States to halt financial assistance to the Palestinian government and to UNRWA compounds an already critical situation.

with 5.8% residing in the West Bank and 33.8% in the Gaza Strip. The increase in overall poverty percentages between 2011 and 2017 is explained by the combined effect of two diverging dynamics: standards of living dramatically worsened in Gaza Strip, causing a rise in the poverty rate of 15 percentage points while poverty decreased by four percentage points in the West Bank. According to the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA), four out of five people living in Gaza's are currently aid-dependent.

Food and nutrition security are closely related to poverty. According to the Socio-Economic and Food Security Survey (FSS-PCBS, 2016), in 2014, 26.8% of total households were classified as severely or moderately food insecure[12]. According to the Food Insecurity Experience Scale (FAO-IFAD-UNICEF-WFP-WHO, 2017), the prevalence of moderate or severe food insecurity in the population was 29.9% between 2014-16, of which 9.5% represented severe food insecurity. Stunting (or height-for-age) stood at 7.4% for children under the age of five in 2014-2016, while the prevalence of wasting (or weight-for height) was only 1.2%. Palestinians also face malnutrition: the prevalence of overweight youth was 8.2% among children under 5 years of age in 2014-2016 (FAO-IFAD-UNICEF-WFP-WHO, 2017). Micronutrient deficiency is also a concern among vulnerable population groups, such as pregnant or lactating women and children.

3.2 An overview of assistance modalities in the West Bank and Gaza Strip

Palestinians are vulnerable to many risks. According to OCHA (2018), the most critical ones are the following: (i) the risk of conflict and violence, forcible displacement, and the denial of access to natural resources, inputs and markets that affect 2 million people in need of protection assistance; (ii) risks associated with poor water quality, poor wastewater collection and treatment, and lack of proper hygiene practices that affect 1.9 million people; (iii) the risks of food insecurity faced by 1.7 million people; and (iv) 1.2 million people are exposed to health and nutrition risks (e.g. conflict-related trauma casualties, pregnant and lactating women, children under the age of five, people with disability and elderly, etc.). Although all Palestinians are negatively impacted by the conflict, some of them – such as 1.4 million refugees, the 1.6 million Gazan civilians in need, and 0.4 million individuals living in Area C – are more severely affected (UNSCO, 2016).

In the face of economic de-development and the denial of autonomous development prospects, humanitarian and development actors increasingly recognize the importance of bridging the humanitarian-development divide in Palestine. The result is a combination of emergency response measures with longer-term interventions to better address the causes of vulnerabilities faced by the Palestinian population (Diakonia, 2018).[13] Many vulnerable

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[12] Preliminary results of the last SEFSec (PCBS, 2018b) show that the share of households classified as severely or moderately food insecure has increased by 6.2% between 2014 and 2018.

[13] The protracted nature of the crisis and the dismal prospects for positive change have led to a considerable degree of critical reflection across the nexus from different perspectives and actors in WBGS. The UN notes that "humanitarian action extends to less traditional areas of intervention and calls for a much closer collaboration between humanitarian actors and the government" (UNSCO, 2016: 17). Along the same lines, the Humanitarian Response Plan for 2018 (OCHA, 2017a: 7 and 30) recognizes that "key drivers of vulnerability are common to both the humanitarian and development needs". As noted by the Mapping and Synthesis of Evaluations carried

groups have been identified as beneficiaries of both humanitarian and development interventions, both of which must occur simultaneously in order to be effective. Humanitarian and development programming are increasingly aligned in order to provide durable and sustainable assistance capable of building resilience and reducing vulnerability. In other words, a blend of interventions tends in practice to prevail on a strict divide between humanitarian and development interventions, leveraging on the "humanitarian-development nexus" and operationalizing the so-called "new way of working" (OCHA, 2017b) as outlined in the UN Secretary-General's Report for the World Humanitarian Summit (UN, 2016).

The most important modalities of assistance in WBGS are: (i) in-kind provision of basic foodstuffs through baskets generally including wheat flour, rice, pulses and vegetable oil; (ii) food vouchers for use on selected items with designated merchants; and (iii) cash transfers distributed mostly through e-cards for cash disbursements. The aforementioned forms of assistance are listed in increasing flexibility, meaning that the mode of assistance provides a greater range of choice to targeted households, has cheaper implementation, and is less likely to focus on basic needs. Vocational training programs and other forms of livelihoods support can also help families rise above the poverty line. Other forms of support such as health and housing assistance are also quite important, especially in acute crisis (e.g. the 2014 war in Gaza).

Assistance in Palestine is delivered by many actors. In terms of financial volume, major implementing actors include the Ministry of Social Development (MoSD), the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA), and the World Food Programme (WFP). While a large number of donors support UNRWA's activities, the two largest donors to direct assistance are the EU and, until 2017, the USA. Charities linked to zakat — the payment made under Islamic law on certain kinds of property used for charitable and religious purposes — as well as assistance through de-facto authorities in the Gaza Strip are equally important sources of financial inflows (Culbert, 2017).

While modalities of assistance vary between implementing bodies and beneficiary groups, selection criteria and program objectives are similar. The principal beneficiary selection tools used by actors for food and social assistance are poverty-based, using variations of a proxy means testing formula.

Institutional structures and political considerations are primary determinants in how social security assistance, direct food assistance and cash assistance are defined and channeled. Some development donors fund through governmental channels, such as the MoSD, while some humanitarian donors fund through humanitarian actors, such as UNRWA or WFP. As a result, the current system of delivering assistance is fragmented despite recent efforts working towards effective coordination between humanitarian and development actors (Culbert, 2017). The recent MoSD's strategy (MoSD, 2017) holds promise in both coordinating and aligning assistance efforts of multiple actors by addressing underlying social-economic challenges. However, this strategy remains at an early policy stage.

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out by UNEG (2018: 28), in the occupied Palestinian territories there is recognition that "the scope of programming needs to transcend standard 'good practice' in order to mitigate the negative effects of what is likely to be a deteriorating situation".

3.3 Assistance to Palestinians in 2013-2014

Assistance to the WBGS is composed of a very heterogeneous set of modalities, implementing bodies and beneficiary groups, reflecting different conditions at the local level as well as between the West Bank and the Gaza Strip.

Types of Assistance

According to SEFSec (FSS-PCBS, 2016), approximately 40% of all Palestinian households reported receiving at least one type of assistance in 2014. There is a marked difference in the share of households receiving assistance in Gaza Strip (84%) compared to the West Bank (less than 17%) (Table1). Between 2013 and 2014, the share of assisted households in the Gaza Strip increased by more than 18%, even greater than the amount observed in 2011 (FAO-UNRWA-WFP, 2013). However, the increase in share of assisted households between 2013 and 2014 in the West Bank was less than 2%, standing 8 percentage points below the level existing in the region in 2011.

Table1 illustrates the prevalence of in-kind food, cash transfers and food vouchers provided to Palestinian households. Between 2013 and 2014, the composition of the various types of assistance in the West Bank did not change significantly, while composition of assistance in the Gaza Strip underwent important changes. In the West Bank, a large share of households reported that "Cash" and "In-kind food" were the two types of the assistance they received the most of in 2013 and 2014. On the other hand, the major cat-

Table 1. Share of households receiving assistance by type of assistance and region, 2013-2014.

	WBGS		West Bank		Gaza Strip	
	2013	2014	2013	2014	2013	2014
In-kind food	24.6%	28.0%	7.5%	7.6%	57.5%	67.0%
Health care	0.4%	2.3%	0.6%	2.7%	0.2%	1.6%
Clothing	0.7%	2.1%	0.4%	0.3%	1.3%	5.7%
Job creation	1.3%	0.3%	0.3%	0.2%	3.2%	0.6%
Compensation martyrs	0.2%	0.3%	0.1%	0.3%	0.4%	0.4%
Cash	16.8%	16.2%	10.5%	8.3%	28.9%	31.2%
Health insurance	11.5%	7.8%	0.7%	1.2%	32.2%	20.3%
Food vouchers	3.0%	8.2%	2.0%	1.6%	4.7%	20.8%
School feeding	0.1%	0.1%	0.1%	0.0%	0.1%	0.4%
Productive inputs	0.1%	0.0%	0.2%	0.0%	0.0%	0.1%
Drinking water	0.4%	1.8%	0.0%	0.1%	1.0%	5.2%
Electricity	0.2%	0.2%	0.2%	0.3%	0.0%	0.2%
Housing[a]	-	9.2%	-	0.9%	-	25.0%
Other	0.6%	1.2%	0.2%	0.0%	1.3%	3.4%
At least one form of assistance	32.4%	39.7%	15.2%	16.5%	65.7%	84.2%

[a] Not included in the 2013 SEFSec survey.
Source: FSS-PCBS (2016): Table 7.1, modified.

egories of assistance reported in the Gaza Strip fluctuated between the two years. New types of assistance outside the three core types ("In-kind food", "Cash" and "Health insurance") were reported in the Gaza Strip. These included "Housing" (shelter, rent, caravan), "Food voucher", "Drinking water" and "Clothing". All four increased significantly between 2013 and 2014 in response to worsening living conditions as a result of the armed conflict.

Value of Assistance

In 2014, assisted households received an average of 102 US$/month. However, national averages mask significant regional differences in both levels and trends. Table 2 reports the average monthly value received by households in the two regions for each types of assistance during 2012-2014. There was a general decline in the average value of assistance for cash and food in the West Bank from 2013 to 2014. Conversely, assistance for employment and provision of agricultural inputs increased. In the Gaza Strip the average value of support increased for many assistance types but food assistance that did not change much. Employment assistance represented the largest average allowances given to households in 2014. Among "Other" forms of support, the largest average values are seen for housing and shelter assistance. Support to agricultural production activities almost disappeared in Gaza Strip after 2012.

The value of assistance varies across different types of households (Table 3). Support to refugee households was slightly greater than that of non-refugee households (107 vs. 91 US$/month). Moreover, a substantial difference was recorded in 2014 based on gender household heading: female-headed households received on average 30% more support than male-headed households (127 vs. 98 US$/month). This reveals that female-headed households are more dependent on assistance, probably due to higher vulnerability.

The composition of assistance across different household typologies emphasizes the different needs of various groups (Table 3). Female-headed households are more likely to receive assistance in the form of cash and free health services than male-headed house-

Table 2. Average value of support by type of assistance, US$/month.

Type of assistance	West Bank			Gaza Strip		
	2012	2013	2014	2012	2013	2014
Cash	115	79	55	95	92	123
In-kind food	45	34	27	37	36	48
Food vouchers	42	43	28	30	48	32
Job creation	115	97	126	82	147	215
Agricultural inputs	46	69	123	129	na	9
Housing	na	na	231	na	na	211
Other[a]	71	70	135	4	17	110
Average per assisted household	128	96	86	65	102	108

[a] The "Other" category in years 2012 and 2013 includes also housing.
Source: FSS-PCBS (2016): Table 7.3, modified.

Table 3. Composition of assistance by region and household group, share of total value received, 2014.

Type of support	West Bank	Gaza Strip	Refugee	Non-refugee	Male-headed	Female-headed
Cash	36.4%	34.5%	31.8%	40.2%	34.0%	40.4%
In-kind food	15.3%	26.8%	23.6%	24.7%	25.7%	15.6%
Health insurance	19.8%	0.8%	5.3%	5.0%	3.1%	16.2%
Food vouchers	3.1%	5.5%	4.7%	5.7%	5.5%	2.3%
Housing	13.1%	21.6%	24.4%	12.2%	20.9%	12.9%
Other	0.1%	5.6%	5.5%	2.2%	5.0%	0.7%
Remaining sources	12.2%	5.2%	4.7%	10.0%	5.8%	11.8%
Average per assisted household (US$/month)	86	108	107	91	98	127

Source: FSS-PCBS (2016): Table 7.4, modified.

holds. This is probably due to the demographic composition of the former, with a majority of households headed by widows and elderly women. The comparison between refugee and non-refugee indicates a cash preference by non-refugee households, while refugee households receive a larger share of assistance in “Other” forms, including substantial support for housing.

Sources of Assistance

Social assistance coverage increased between 2013 and 2014, reflecting deteriorating livelihood conditions–especially in the Gaza Strip, where more than four households out of five were receiving assistance in 2014. Overall, reported sources of assistance are given primarily by the Palestinian Ministry of Social Affairs (currently renamed the Ministry of Social Development, or MoSD), UNRWA, international agencies, charitable and religious associations, and informal assistance (family, relatives or friends). However, key differences are observed between the West Bank and the Gaza Strip (Table 4).

In the West Bank, 7% of households reported receiving assistance from the Ministry of Social Affairs in 2014, a slightly lower figure than that reported in 2013 (8%). The other two most cited sources of assistance in 2014 were UNRWA and informal assistance (family and relatives), which remained unchanged from 2013 levels.

A different picture emerges from the data in the Gaza Strip. Not surprisingly, the largest source of social assistance in 2014 was UNRWA, an organization that provided food assistance to some 867,000 refugees. A number of other sources of assistance were reported, including the Palestinian Ministry of Social Affairs, international agencies, charitable and religious associations, worker unions, and family and friends. Informal sources of social assistance more than halved, dropping to 7% in 2014. This is a clear sign that informal social networks were unable to help in times of widespread severe hardship caused by the war.

Table 4. Reported sources of assistance by Region[a].

	West Bank		Gaza Strip	
	2013	2014	2013	2014
Ministry of Social Affairs	8.2%	6.8%	19.6%	23.5%
Other PA agencies	0.9%	2.0%	4.2%	8.6%
Political parties	0.0%	0.1%	0.4%	8.6%
Zakat/other religious institutions	0.5%	0.6%	0.5%	2.7%
International agencies (excluding UNRWA)	1.4%	1.2%	9.3%	21.3%
UNRWA	2.1%	4.0%	42.6%	62.3%
Arab countries	0.0%	0.1%	0.3%	2.8%
Charity/religious	0.4%	0.3%	3.8%	19.5%
Family and relatives	2.8%	2.8%	14.8%	6.8%
Friends/Neighbors	1.1%	0.9%	1.8%	4.8%
Workers union	0.0%	0.0%	21.6%	12.9%
National banks	0.0%	0.0%	0.0%	0.5%
Local reform commission	0.0%	0.0%	0.1%	0.6%
Other	0.4%	0.9%	0.3%	3.3%
Any type of assistance	15.2%	16.5%	65.7%	84.2%

[a] Sources of assistance are not mutually exclusive. Some households reported receiving assistance from more than one source.
Source: FSS-PCBS (2016): Table 7.5.

4. Poverty and Food Security

The profiling of Palestinian households in terms of poverty quartiles before receiving assistance shows expected patterns[14] (Table 5): moving from poorer to richer households saw a parallel decrease in household size, an increase in educational attainment, a decrease in the dependency ratio, and an increase in the employment rate (including that of the head of the household).

Poverty in the WBGS is determined by the employability of household members. Food security on the other hand is largely influenced by access dimension, specifically by individuals' labor entitlement. Table 6 therefore provides a detailed account of household heads' labor indicators across poverty quartiles. By and large, poorer households had more problematic labor conditions. For instance, household heads who worked fewer hours were more likely to be poor, just as irregular employment and lower level occupations were more related to poverty. Usually, poverty is correlated to employment in the primary and construction sectors. In short, heads of poorer households tend to have more informal and irregular jobs that do not require high levels of formal skills and/or education, such as jobs in basic production sectors.

[14] Only the female-headed household share does not show a clear pattern. Another characteristic (not reported in the table) that does not change at all is the number of sources of income per household: on average, two per household.

Table 5. Households' profile per poverty quartile, 2013.

	Q1	Q2	Q3	Q4	Total
Average household size	7.7	5.2	4.8	4.5	5.6
Share of HH with female head	6.4%	11.5%	11.4%	9.1%	9.6%
Share of HH with head with secondary education or above	28.1%	34.2%	39.1%	51.0%	38.1%
Global dependency ratio	1.20	1.19	1.02	0.90	1.08
Share of HH whose head does not work	28.9%	28.4%	23.5%	22.4%	25.8%
Household employment rate	32.1%	36.9%	40.5%	43.7%	38.3%

Authors' elaboration on SEFSec 2014 data.

Table 6. Head of household employment statistics per poverty quartile, 2013.

	Q1	Q2	Q3	Q4	Total
Working Status					
Employed from 1-14 hours	5.1%	4.6%	2.5%	1.3%	4.2%
Employed 15-34 hours	6.1%	6.9%	5.1%	3.2%	6.0%
Employed 35 hours and over	41.7%	46.5%	58.5%	63.5%	47.7%
Temporarily absent	14.6%	10.6%	6.6%	3.9%	11.2%
Looked for a job (already worked)	6.9%	3.9%	1.2%	2.1%	4.6%
Looked for a job (never worked)	2.1%	2.6%	0.7%	1.1%	1.9%
Did not look for work because of frustration	0.7%	0.9%	0.6%	0.6%	0.7%
Full time student	0.1%	0.0%	0.0%	0.0%	0.0%
Housewife	4.0%	5.0%	4.9%	3.4%	4.4%
Unable to work	16.8%	14.7%	12.8%	8.1%	14.8%
Other	0.0%	0.0%	0.2%	0.0%	0.0%
Professional Status					
Employer	2.4%	2.2%	3.9%	11.9%	5.1%
Self-employed	11.3%	11.5%	12.4%	13.9%	12.3%
Unpaid family worker	0.2%	0.1%	0.3%	0.1%	0.2%
Waged employee	61.9%	59.9%	60.5%	52.2%	58.6%
Sector of employment					
Agriculture, fishing and forestry	8.7%	6.7%	3.5%	2.2%	5.3%
Mining, quarrying and manufacturing	6.5%	8.6%	11.5%	13.6%	10.0%
Construction	18.2%	16.7%	16.3%	12.6%	16.0%
Commerce, restaurants and hotels	10.9%	11.2%	14.6%	20.2%	14.2%
Transportation, storage and communication	7.2%	5.5%	6.1%	5.1%	6.0%
Services and other activities	24.3%	24.9%	25.1%	24.5%	24.7%

Authors' elaboration on SEFSec 2014 data.

As expected, there is a direct relationship between poverty and food insecurity (Table 7). This is measured by the Food Consumption Score (FCS) and the Household Food Insecurity Access Scale (HFIAS), two proxies for the qualitative and quantitative dimen-

Table 7. Households' assistance and food security status per poverty quartile, 2013.

	Q1	Q2	Q3	Q4	Total
Per capita expenditure (NIS/month)	305	461	593	860	554
Share of HH receiving assistance	62.5%	41.8%	21.3%	7.6%	33.3%
Average value of assistance per HH (NIS/month)	418	293	347	321	368
Households with insufficient dietary quantity (HFIAS)	50.7%	29.3%	14.8%	6.4%	25.3%
Households with poor or borderline FCS	30.4%	26.4%	17.8%	10.2%	21.2%
Average household FCS	70	72	76	80	74

Authors' elaboration on SEFSec 2014 data.

sions of food security, respectively (cf. section 5.1). Probably the most striking indicator related to poverty is the share of households receiving assistance. This value encompasses almost two thirds of all households in the lowest quartile and 7.6% of households in the highest quartile. Both indicators of food security show the expected regularities in that poorer households have lower FCS values. Meanwhile, poorer households have larger shares of poor or borderline FCS (Q1 three times larger than that of Q4) as well as insufficient dietary quantities (HFIAS in Q1 eight times larger than that of Q4). Quite surprisingly, the average value of assistance rapidly decreases from the lowest to the second-lowest quartile, but then increases again in the two higher quartiles[15].

5. Data and methods

5.1 Data

The Socio-Economic and Food Security (SEFSec) survey has been administered since 2009 to monitor the status of food security among Palestinian households. The SEFSec methodology accounts for the multi-dimensional drivers of food insecurity in WBGS by exploring topics such as asset-based poverty, food consumption, and resilience. This is done to capture the capacity households have to adapt, transform and cope with shocks. Besides these three main pillars, the questionnaire collects data on aspects such as socio-demographics, assistance, expenditure and consumption, all of which are useful for the analysis.

The dataset includes data from the fifth and sixth SEFSec surveys. Data collection took place in 2014 and 2015, with a reference period covering the six months preceding the interview (the second half of 2013 and 2014, respectively). The 2013 SEFSec survey was conducted on a sample of 7,503 households (4,949 in the West Bank and 2,554 in the Gaza Strip), while the 2014 sample included 8,177 households (5,047 in the West Bank and 3,130 in the Gaza Strip). The samples are representative for various levels of disaggregation, including gender, refugee status, governorate, locality type (i.e. urban, rural and refugee camp) and, for the West Bank only, Areas A/B and C (FSS-PCBS, 2016).

An important feature of the 2013-2014 SEFSec is that 92% of the households interviewed in 2013 were included also in the 2014 wave. Therefore, a sample of 6,881 units

[15] However, this seems to be related to the higher average value of assistance in the West Bank to households that own some type of business: essentially, it is a support to investment that is able to generate employment.

(4,454 in the West Bank and 2,427 in the Gaza Strip) can be used to analyze the impact of assistance on Palestinian households through the panel structure of the dataset.

The main variables used in the analysis are summarized in Table 8. They include the three outcome variables of interest: a measure of poverty and two measures of food security (i.e. HFIAS and FCS, the latter also broken down in its main components), a set of household socio-demographics that are the usual correlates used to analyze the outcomes, and some geographical dummies to account for regional/residence differences used to capture any unobserved heterogeneity.[16]

Poverty outcomes are measured as an asset-based poverty index closely related to living standards. An asset-based poverty index better reflects long-term wealth over an expenditure-based poverty index, a short-term measure which in principle would work better in an impact evaluation of aid effectiveness. Additionally, the asset-based poverty index was chosen since total household expenditure is not accurately sampled by the SEFSec questionnaire. Indeed, an assessment commissioned by SEFSec administrators to evaluate the robustness and reliability of expenditure-based poverty measures resulted in the decision to abandon money-based (i.e. expenditure) measures of poverty because they were inconsistent with similar measures based on benchmark data from the Palestine Expenditure and Consumption Survey of 2011 (PECS) (Langworthy *et al.*, 2014; Smith, 2014).[17] Furthermore, in the context of protracted crisis such as the currently ongoing one in Palestine, assistance becomes a key source of income for the majority of households, establishing itself as a "structural" component of household income. Assistance has significantly contributed to building household assets over the years and helps maintain a given level of standards of living via consumption smoothing. If assistance to households decreases, household assets would decrease in response because the household sells its assets to countervail the reduction in assistance.

Food security is proxied by two measures, namely the Household Food Insecurity Access Scale (HFIAS), a quantitative measure of the dimension of food consumption (Coates *et al.*, 2007), and the Food Consumption Score (FCS) that captures the quality of household diets (WFP, 2008). HFIAS is an indicator based on responses to nine questions, five of which relate to the size and frequency of meals consumed in the 30 days preceding the survey. HFIAS is value ranging from 0 to 27, where a higher score indicates an insufficient dietary quantity. FCS is an indicator based on the number of days specific food groups are consumed in the seven days preceding the survey. The FCS is a continuous score where a value less than or equal to 45 or between 45 and 62 respectively indicate poor or borderline food consumption. This value is obtained by assigning a specific weight to each food group in accordance to its contribution to dietary quality.

[16] The variables listed in Table 3.1 are the ones actually used in the following analysis, that is they are only a subset of the wider set of candidate variables that in principle could be used. Unfortunately, the SEFSec survey is designed only to monitor the evolution of food security in Palestine. As such it does neither have the wealth of variables that can be usually found in a standard multi-purpose survey (e.g. household cultural traits, household behavior other than food consumption, etc.), nor the depth of data typical of household expenditure/consumption surveys (e.g. detailed information on household expenditures, food consumption composition, etc.).

[17] The overall conclusion of these studies was that "in the absence of other options, an asset-based measure of poverty can thus serve as a valid, stand-alone measure for the purposes of the SEFSec food insecurity analysis." (Smith, 2014: 21).

Table 8. Summary statistics of key variables.

Variable	Meaning	Mean	Standard deviation	Min	max
l_ass_index	Log of asset based poverty index	7.09	0.33	5.52	8.28
fcs	Food consumption score (FCS)	74.28	17.06	0.00	112.00
hfias	Household Food Insecurity Access Scale (HFIAS) score	4.64	6.56	0.00	27.00
vegfru_fcs	FCS cereals, tubers, pulses, vegetable and fruit	26.96	4.93	0.00	49.00
meatmilk_fcs	FCS meat and milk	40.85	14.65	0.00	56.00
oilsug_fcs	FCS fats and sugar	6.46	1.13	0.00	7.00
mass	log of HH monthly assistance	1.96	2.63	0.00	10.82
ydum	dummy for year 2014	0.50	0.50	0.00	1.00
massy	interaction mass*ydum	1.04	2.12	0.00	10.82
lhsize	Log of household size	1.81	0.42	0.69	3.30
lexp	Log of household monthly expenditure (NIS)	7.72	0.75	1.79	11.16
dep_ratio	Dependency ratio (aged 0-15+aged >65)/aged 15-65	1.10	1.34	0.00	7.00
rat_emp	% of employed people aged >15 in the HH	0.37	0.24	0.00	1.00
agehead	Age of HH head (years)	45.34	14.37	19.00	98.00
femhead	HH head gender (female = 1)	9.66%		0	1
head_ref	HH head status (refugee = 1)	41%		0	1
high_ed	HH head education (secondary education or higher = 1)	38.12%		0	1
employed	HH head occupational status (employed = 1)	70.42%		0	1
qly_deprived	HH with low FCS (< 61) (yes = 1)	22.26%		0	1
qty_deprived	HH with insufficient food intake, HFIAS (yes = 1)	23.21%		0	1
ass	HH receiving assistance (yes = 1)	37.71%		0	1
WB North	Regional dummy (West Bank North = 1)	27.58%		0	1
WB Center	Regional dummy (West Bank Center = 1)	17.69%		0	1
WB South	Regional dummy (West Bank South = 1)	19.46%		0	1
GS North	Regional dummy (Gaza Strip North = 1)	18.47%		0	1
GS Center	Regional dummy (Gaza Strip Center = 1)	5.19%		0	1
GS South	Regional dummy (Gaza Strip South = 1)	11.61%		0	1
rural	Locality of residence (rural = 1)	18.62%		0	1
camp	Locality of residence (refugee camp = 1)	9.74%		0	1
urban	Locality of residence (urban = 1)	71.64%		0	1

The pros and cons of these two indicators have been assessed in several review and validation studies of food security indicators (Carletto *et al.*, 2013). IFPRI (2006) concluded that the FCS weighting system for the food frequency scores might not be able to accommodate variations across space and time. Nevertheless, IFPRI found positive associations between FCS values and caloric consumption per capita in some studies. The information generated by HFIAS is used to assess the prevalence of household food security and detect changes over time. Moreover, validations conducted in Latin America and sub-Saharan Africa (Melgar-Quinonez *et al.*, 2006; Knueppel *et al.*, 2010) found that the indicator demonstrated reliability and validity in the local contexts in which it was deployed.

Besides the considerations above, the SEFSec dataset does not include enough data to build other food security indicators such as the food caloric intake.

5.2 Methods

To estimate the impact of assistance on a given dimension of well-being, such as poverty or food security, we need to control for possible unobserved heterogeneity in participation in the assistance program. Due to the targeting strategies of the different agencies that provide assistance to Palestinian households, treated households are quite different from untreated ones. Notably, the probability of receiving assistance is correlated with a set of characteristics mostly related to poverty (cf. section 4). As a result, the selection bias is likely to be pervasive (Khandker *et al.*, 2010). Moreover, further unobserved targeting variables may affect both the outcome variable and the probability to receive assistance.

Building on the panel structure of SEFSec dataset, we used a difference-in-difference (DD) approach to get rid of aforementioned biases. The DD model assumes that the heterogeneity in participation is fundamentally time invariant once conditioned on a set of household characteristics (**X**):

$$E(Y^0_t - Y^0_{t-1} \mid T = 1,\mathbf{X}) = E(Y^0_t - Y^0_{t-1} \mid T = 0,\mathbf{X}) \quad (1)$$

where Y^0_t is the potential outcome without the treatment measured at time t. T is the treatment status, which equals to 1 if the household received assistance and 0 otherwise. The assumption of time invariant heterogeneity implies that the dynamics observed in the control group are the same as the ones observed in the treated group had the latter not been treated. Unfortunately, the SEFSec dataset does not allow testing for the "parallel trend" hypothesis. However, considering the short time distance between the two SEFSec waves, the risk that this assumption does not hold is low.

In regression form the DD estimator is given by:

$$Y_{i,t} = \alpha_i + \beta T_i + \gamma t + \delta T_i t + \Sigma \zeta X_{i,t} + \varepsilon_{i,t} \quad (2)$$

where t is a time dummy (1 in the second period, 0 otherwise). T_i is the treatment dummy, with a value of 1 for the treatment group and 0 for the control. The casual effect of the treatment is assumed to be additive. In the classical DD model, the δ parameter — which is associated with the interaction term between the treatment T_i and the time dummy variable t — identifies the expected impact (Angrist and Pischke, 2008).

The traditional DD regression uses dichotomic (i.e. treated/non-treated) treatment variables. However, continuous treatment variables measuring the intensity of the treatment can be also used (Card, 1992; Acemoglu *et al.*, 2004). Continuous variables fully exploit the information content of available data. For the purpose of this study, the most suitable candidate is the monthly value of assistance received by the household. In this case, it can be demonstrated that for the i-th household the δ parameter is equivalent to:

$$\delta = \frac{(Y_{i1} - Y_{i0} \mid T_i = T_{i1}, X_i) - (Y_{i1} - Y_{i0} \mid T_i = T_{i0}, X_i)}{\mathrm{T}_{i1} - \mathrm{T}_{i0}} \quad (3)$$

where the numerator is the difference in outcome variation over time given the final and initial values of the continuous intervention variable and the denominator is the difference between the final and the initial value of the continuous treatment variable. In the case of an increase of the continuous treatment variable between the two periods, a positive value of δ indicates that the increased treatment intensity determines a higher increase of the outcome variable. This implies that the impact of the treatment is positive.

Moreover, thanks to the time dimension of the panel, we can include in (2) household specific intercepts or fixed effect, α_i. Irrespective of the adopted fixed effect estimator, this is equivalent to including a dummy variable for each household in equation (2) (Wooldridge, 2013). Equation (3) will still hold provided that we condition on both $\mathbf{X}$ and α_i.

The key identifying assumption in this context is that treatment intensity is not correlated with individual unobserved trends, although it can correlate with individual permanent characteristics. We posit that the intensity of assistance ("mass", measured in logarithms) impacts the outcome variable, i.e. either the log of poverty asset index ("l_assindex") or one of the food security indicators ("hfias" or "fcs"). The intensity of assistance and the outcome variable are both affected by a set of household characteristics that we assume to be time-invariant, including location, refugee status, and education of the head of household. All of these are captured by α_i. We further conditioned on potential time variant confounders such as dependency ratio, household size, ratio of employed household members to the number of household members of working age, and employment status of the head of the household. In the case of poverty models potential endogeneity may remain even after having conditioned on the fixed effects due to the nature of the targeting process. Therefore, we implemented the 2SLS version of both the pooled OLS and the fixed effect estimators. In the case of food security indicators, we can assume that regressors are exogenous because targeting is made on poverty, not on food security indicators.

Noticeably, in the case of the HFIAS score, we have to deal with a censored variable whose distribution has a clear peak at zero. In such a case the fixed effects tobit model estimates would be affected by the so-called "incidental parameters" problem especially in case of short time panel datasets (Greene, 2004). To ensure consistency with the fixed effect models of continuous outcome variables (asset-based poverty index and FCS), in the case of HFIAS model we used the semi-parametric estimator of fixed effect tobit models proposed by Honoré (1992), which is consistent and asymptotically normal even for time dimension of 2 as in our case.

6. Results

We first run a pooled OLS regression using a sandwich estimator of the covariance matrix. Results in the case of the asset-based poverty index[18] are reported in the first two columns of Table 9. All independent variable parameters except for a few regional dummies are significant at p=0.05. Both the household size and the dependency ratio affect the index negatively, while the ratio of employed household members over working age

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[18] The dependent variable – i.e., the log of the asset-based poverty index – is built in such a way a higher index value corresponds to wealthier households. This should be considered when interpreting the results in Table 9.

Table 9. Asset-based poverty index regression models, Palestine.

	Pooled OLS		Pooled 2SLS		Fixed Effect		Fixed Effect IV	
	Coef.	Student's t	Coef.	z	Coef.	Student's t	Coef.	z
mass[a]	-0.03	-24.96	-0.03	-25.33	-0.02	-15.56	-0.02	-15.07
ydum	-0.01	-1.89	-0.01	-1.91	-0.03	-5.18	-0.03	-5.07
massy[a]	0.00	2.06	0.00	2.11	0.01	6.04	0.01	5.75
lhsize	-0.31	-54.19	-0.31	-54.22	-0.27	-37.46	-0.27	-37.47
dep_ratio	-0.02	-14.26	-0.02	-14.23	-0.02	-10.77	-0.02	-10.77
rat_emp	0.10	8.53	0.10	8.47	0.15	12.29	0.15	12.32
employed	0.04	5.55	0.03	5.35	-0.01	-4.20	-0.01	-4.20
agehead	0.00	10.45	0.00	10.42				
refhead	0.04	8.5	0.04	8.47				
femhead	-0.02	-2.77	-0.02	-2.70				
high_ed	0.09	19.05	0.09	18.85				
WB North	0.13	13.33	0.12	12.84				
WB Center	0.23	22.58	0.23	21.98				
WB South	0.09	9.25	0.09	8.83				
GS North	-0.01	-1.01	-0.01	-1.05				
GS Center[b]								
GS South	-0.01	-1.03	-0.01	-1.01				
rural	-0.10	-16.06	-0.10	-15.98				
camp	-0.04	-5.06	-0.03	-5.01				
constant	7.44	417	7.45	415.01				
R^2	0.45				0.36			
KP rk under-identification ChiSq							p=0.00	
CD Wald F			>350				>350	
HJ over-identification ChiSq			exactly id.				exactly id.	
IV (excluded)			ass, assy				ass, assy	
F test of fixed effect					1.8	p=0.00		

[a] This variable has been instrumented; [b] GS Center, where Gaza City is located, is assumed as reference.
Note: KP is the Kleibergen-Paap LM test for under-identification of the model; CD is the Cragg Donald weak identification test; HJ is the Hansen J statistics for over-identification of the model (cf. Baum *et al.*, 2007).

household members shows a clear positive effect. This confirms that poverty is mostly a matter of (a lack of) employability. The characteristics of head of households that positively impact the index are the following: education, age, employment status, refugee status or living in the West Bank. On the other hand, households situated in rural areas and refugee camps negatively impact the outcome variable. All estimates have expected signs: higher educational attainment, employment and living in the West Bank over the Gaza Strip all decrease the chances that a household is poor. Conversely, holding refugee status or living far away from an urban center increases the likelihood of being poor.

The impact denoting the intensity of assistance is captured by the interaction term "massy". The value of monthly assistance positively impacts the asset-based poverty index.

However, despite being statistically significant, the coefficient estimate is close to 0. To deal with possible endogeneity, we performed a pooled 2SLS instrumenting the variable and the interaction term with dummies for assistance and its interaction with time. However, the size of the coefficient of the interaction term does not change in the case of 2SLS.

In order to account for unobserved individual heterogeneity, we run a fixed effect regression. This is done because the Hausmann test rejected the hypothesis of absence of correlation between random effects and regressors. Table 9 reports the parameter estimates obtained with the fixed effect estimator on transformed data as deviations from the group means.[19] We also implemented the corresponding 2SLS version for the fixed effect estimator using the same instruments employed in the pooled model (last two columns of Table 9). All time-invariant regressors are perfectly correlated with the household specific intercepts, therefore only the time varying variables are considered in the fixed effect models: dependency ratio, household size, ratio of employed household members to working age members, and employment status of household head. Both models confirm that the intensity of assistance has a significant effect in reducing household poverty. In all the models, the coefficients of the interaction term are statistically significant stable around 0.01: a 10% increase of assistance on average leads to a direct 0.1% increase of the asset-based index.

To take into account the fact that the West Bank and the Gaza Strip are physically, politically and economically apart, we estimated the impact of assistance separately for the two regions (Table 10 and 11, respectively). As expected, the impact is significantly positive in the West Bank and of the same order of magnitude as Palestine as a whole (Table 9). This was true after having accounted for individual heterogeneity.

Quite surprisingly, we obtained a non-significant impact of assistance in the Gaza Strip. This seems related to the very peculiar situation present in Gaza. In 2014, more than four households out of five received assistance (cf. section 3.3), largely irrespective of the household characteristics.[20] This was done in order to offset the region's widespread humanitarian crisis resulting from a ten-year long blockade and generalized "de-development" (UNCTAD, 2017). To make matters worse, a series of military operations took place over the last decade, ultimately culminating in the devastating war of July-August 2014 — exactly during the second period surveyed. This is likely to have blurred the causal relationship between assistance and poverty.

The estimates in the case of HFIAS show the expected signs.[21] In the models for Palestine as a whole (Table 12), the coefficient of the interaction term is significantly negative in the simple pooled OLS model as well as in models addressing the censored nature of the HFIAS variable. This means that assistance has a significant positive impact in ensur-

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[19] With this transformation we get rid of the large number of group dummies that would be included in the least square dummy variable estimator had the transformation not being made (Baltagi, 2005).

[20] The poverty headcount ratio in the Gaza Strip is 53.0% while one third of population (33.8%) lives in extreme poverty according to monthly consumption patterns (PCBS, 2018a). According to Atamanov and Palaniswamy (2018) more than 90% of the bottom 40% in the Gaza Strip receive some form of aid; and even among the most well-off, half receive assistance. Another anecdotal evidence of the generalized humanitarian crisis is the higher concentration around the mean of average assistance per household in Gaza Strip vis-à-vis West Bank with the latter having a coefficient of variation that is five times larger than the former.

[21] HFIAS is a measure of quantity deprivation of food showing higher scores the lesser the food consumed by the household.

Table 10. Asset-based poverty index regression models, West Bank.

	Pooled OLS		Pooled 2SLS		Fixed Effect		Fixed Effect IV	
	Coef.	Student's t	Coef.	z	Coef.	Student's t	Coef.	z
mass[a]	-0.03	-16.29	-0.03	-17.15	-0.02	-10.01	-0.03	-10.15
ydum	-0.02	-3.02	-0.02	-3.01	-0.03	-5.55	-0.03	-5.42
massy[a]	0.00	0.53	0.00	0.47	0.01	3.61	0.01	3.34
lhsize	-0.30	-38.49	-0.30	-38.49	-0.23	-25.1	-0.23	-25.13
dep_ratio	-0.02	-10.99	-0.02	-10.94	-0.02	-8.25	-0.02	-8.24
rat_emp	0.09	5.91	0.09	5.85	0.16	9.82	0.15	9.72
employed	0.05	5.89	0.05	5.66	-0.02	-4.01	-0.02	-3.97
agehead	0.00	8.03	0.00	8.00				
refhead	0.05	7.31	0.05	7.26				
femhead	-0.02	-1.86	-0.02	-1.77				
high_ed	0.10	15.75	0.10	15.68				
WB North	-0.11	-14.93	-0.11	-14.85				
WB Center[b]								
WB South	-0.15	-18.74	-0.15	-18.64				
rural	-0.11	-16.37	-0.11	-16.25				
camp	-0.07	-5.69	-0.07	-5.63				
constant	7.63	345.45	7.63	345.47				
R^2	0.31				0.21			
KP rk under-ident. ChiSq			1083	p=0.00			1013	
CD Wald F			>350				>350	
HJ over-identific. ChiSq			exactly id.				exactly id.	
IV (excluded)			ass, assy,				ass, assy	
F test of fixed effect					1.8	p=0.00		

[a] This variable has been instrumented; [b] WB Center, where Ramallah and East Jerusalem are located, is assumed as reference.
Note: KP is the Kleibergen-Paap LM test for under-identification of the model; CD is the Cragg Donald weak identification test; HJ is the Hansen J statistics for over-identification of the model (cf. Baum *et al.*, 2007).

ing the consumption of adequate quantities of food. Moreover, being a refugee, employed, well-educated, younger household head reduces household food insecurity.

Regional models tell the same story, although it is worth noting that the impact of assistance is much stronger in the Gaza Strip than in the West Bank. This confirms the key role of assistance to ensure food security in a humanitarian crisis context such as the Gaza Strip, where two third of households receive in-kind food assistance and one fifth of surveyed households received food vouchers (cf. Table 1). In the West Bank, households have a wider portfolio of coping strategies available to them, including non-assistance strategies.

Both regions have marked sub-regional differences. The governorates of the two main economic centers – Ramallah and East Jerusalem in the West Bank and Gaza City in the

Table 11. Asset-based poverty index regression models, Gaza Strip.

	Pooled OLS		Pooled 2SLS		Fixed Effect		Fixed Effect IV	
	Coef.	Student's t	Coef.	z	Coef.	Student's t	Coef.	z
mass[a]	-0.03	-14.98	-0.03	-14.38	-0.02	-9.32	-0.02	-8.74
ydum	0.03	2.67	0.03	2.17	0.00	-0.11	0.00	-0.16
massy[a]	0.00	-1.5	0.00	-1.08	0.00	1.34	0.00	1.15
lhsize	-0.35	-43.49	-0.35	-43.28	-0.33	-33.63	-0.33	-33.69
dep_ratio	-0.02	-9.1	-0.02	-9.11	-0.02	-6.81	-0.02	-6.82
rat_emp	0.14	7.86	0.14	7.86	0.12	7.46	0.12	7.49
employed	0.00	-0.17	0.00	-0.20	-0.01	-1.45	-0.01	-1.46
agehead	0.00	7.82	0.00	7.80				
refhead	0.02	3.06	0.02	3.06				
femhead	-0.02	-2.13	-0.02	-2.11				
high_ed	0.07	11.34	0.07	11.14				
GS North	0.00	0.36	-0.01	-1.05				
GS Center[b]								
GS South	0.00	-0.09	0.00	-0.08				
rural	0.01	0.4	0.01	0.40				
camp	-0.01	-0.9	-0.01	-0.88				
constant	7.52	314.63	7.52	312.85				
R^2	0.48				0.46			
KP rk under-identific. ChiSq							p=0.00	
CD Wald F			>350				>350	
HJ over-identification ChiSq			exactly id.				exactly id.	
IV (excluded)			ass, assy				ass, assy	
F test of fixed effect					1.5	p=0.00		

[a] This variable has been instrumented; [b] GS Center, where Gaza City is located, is assumed as reference.
Note: KP is the Kleibergen-Paap LM test for under-identification of the model; CD is the Cragg Donald weak identification test; HJ is the Hansen J statistics for over-identification of the model (cf. Baum *et al.*, 2007).

Gaza Strip – perform on average better than other districts. We do not have econometric evidence to explain this. However, we can argue that this happens for different reasons on the basis of secondary information. For instance, in the case of the West Bank, residing within the municipality of Ramallah or close to it is an advantage in terms of employment and market opportunities. Furthermore, the impact of Israeli settlements and territorial fragmentation is less pronounced in these areas compared to WB North and WB South. For the Gaza Strip, residing close to the decision-making center of the de facto ruling authority and further away from the Israeli border[22] is an advantage in terms of food security.

[22] Israeli forces enforce a buffer zone by land and sea, the "access restricted areas". According to Israeli authorities, up to 100 meters from the double wired/concrete fence built along the Gaza-Israel border is a "no go" area and up to 200 meters there is no access for heavy machinery. However, "humanitarian partners in the field have

Table 12. HFIAS regression models.

Variables	Palestine						West Bank						Gaza Strip					
	Pooled OLS		Tobit		Honoré estimator		Pooled OLS		Tobit		Honoré estimator		Pooled OLS		Tobit		Honoré estimator	
	Coef.	Student's t	Coef.	z	Coef.	z	Coef.	Student's t	Coef.	z	Coef.	z	Coef.	Student's t	Coef.	z	Coef.	z
mass	0.82	22.82	1.17	22.37	0.93	12.62	0.61	12.04	0.61	12.04	0.97	7.27	0.97	16.46	1.40	16.80	1.18	11.84
ydum	-1.34	-13.69	-2.51	-11.08	-3.45	-12.14	-1.47	-14.93	-1.47	-14.93	-4.45	-13.29	-0.69	-1.99	0.24	0.43	0.90	1.33
massy	-0.40	-9.73	-0.26	-4.22	-0.35	-4.53	-0.21	-3.24	-0.21	-3.24	-0.35	-2.1	-0.58	-7.51	-0.78	-6.84	-1.16	-8.1
lhsize	2.43	19.82	4.51	19.71	3.90	11.17	1.73	13.13	1.73	13.13	4.05	7.42	3.62	14.19	4.71	13.75	3.95	8.38
dep_ratio	0.05	1.36	0.15	2.27	0.10	0.99	0.02	0.46	0.02	0.46	0.11	0.7	0.16	1.85	0.25	2.16	0.10	0.67
rat_emp	-1.84	-8.08	-3.68	-7.77	-3.37	-4.7	-1.04	-4.27	-1.04	-4.27	-3.36	-3.26	-3.79	-7.63	-5.59	-7.75	-3.45	-3.29
employed	-0.93	-6.51	-1.30	-5.15	-1.32	-3.36	-0.85	-5.44	-0.85	-5.44	-1.52	-2.48	-0.68	-2.39	-0.41	-1.13	-1.17	-2.21
agehead	-0.03	-9.13	-0.05	-8.19			-0.02	-5.03	-0.02	-5.03			-0.06	-8.16	-0.08	-7.70		
refhead	-0.25	-2.26	-0.81	-3.94			-0.41	-3.41	-0.41	-3.41			-0.21	-0.94	-0.27	-0.92		
femhead	0.18	0.99	0.67	2.05			0.36	1.86	0.36	1.86			-0.05	-0.13	-0.04	-0.09		
high_ed	-1.32	-13.69	-2.66	-13.89			-0.87	-8.88	-0.87	-8.88			-2.02	-9.44	-2.68	-9.44		
WB North	-1.10	-4.43	-2.79	-7.00			0.71	6.04	0.71	6.04								
WB Center[a]	-1.75	-6.9	-5.15	-11.56														
WB South	-0.73	-2.86	-0.72	-1.79			1.16	9.29	1.16	9.29								
GS North	2.22	8.54	2.58	6.93			0.19	1.61	0.19	1.61			2.10	7.95	2.28	6.22		
GS Center[b]							1.30	5.27	1.30	5.27								
GS South	2.15	7.92	2.45	6.36			1.91	5.08	1.91	5.08			2.09	7.6	2.32	6.09		
rural	0.02	0.18	0.43	1.67									-1.59	-2.97	-3.21	-3.97		
camp	1.42	7.28	2.70	9.20									1.59	5.37	2.20	5.81		
constant	3.25	7.73	-0.72	-0.96									2.63	3.33	-1.36	-1.24		
R^2	0.31						0.23						0.23					

[a] WB Center, where Ramallah and East Jerusalem are located, is assumed as reference in the West Bank model; [b] GS Center, where Gaza City is located, is assumed as reference in both the Palestine and Gaza Strip models.

Table 13. FCS regression models.

Variables	Palestine				West Bank				Gaza Strip			
	Pooled OLS		Fixed effects		Pooled OLS		Fixed effects		Pooled OLS		Fixed effects	
	Coef.	Student's t	Coef.	Student's t	Coef.	Student's t	Coef.	Student's t	Coef.	Student's t	Coef.	Student's t
mass	-0.84	-9.64	-0.58	-6.22	-0.80	-6.36	-0.70	-6.22	-1.14	-8.54	-1.04	-6.22
ydum	-0.01	-0.04	-0.27	-0.78	0.35	0.98	-0.10	-0.28	-1.93	-1.98	-3.78	-3.28
massy	-0.26	-2.28	-0.22	-1.68	0.21	1.19	0.58	2.63	-0.13	-0.64	0.27	1.01
lhsize	3.29	8.79	4.51	9.22	3.34	7.37	4.42	7.57	3.84	5.81	5.11	5.76
dep_ratio	0.27	2.44	0.26	1.82	0.29	2.21	0.29	1.76	0.09	0.38	0.10	0.33
rat_emp	7.68	11.03	8.27	9.85	6.96	8.57	8.51	8.48	9.79	7.31	8.03	5.3
employed	1.25	2.98	-0.46	-2.1	1.39	2.74	-0.47	-1.84	0.62	0.85	-0.43	-1.02
agehead	0.07	6.1			0.05	4.31			0.09	4.51		
refhead	-0.45	-1.44			0.61	1.58			-2.59	-4.69		
femhead	-0.86	-1.62			-0.75	-1.19			-1.02	-1.03		
high_ed	3.28	11.16			2.83	8.07			3.46	6.42		
WB North	-0.67	-0.93			-0.77	-1.89						
WB Center[a]	0.00	0										
WB South	-9.88	-13.15			-10.43	-22.66						
GS North	-5.76	-7.95							-4.81	-6.54		
GS Center[b]												
GS South	-7.49	-9.71							-6.70	-8.6		
rural	-1.26	-3.42			-1.90	-4.95			4.24	3.15		
camp	-1.69	-3.07			-4.42	-5.75			0.67	0.86		
constant	67.27	53.95			66.28	49.87			68.57	34.38		
R^2	0.13		0.06		0.13		0.03		0.13		0.06	
F test of fixed effect		1.28	p=0.0			1.36	p=0.0			1.28	p=0.0	

[a] WB Center, where Ramallah and East Jerusalem are located, is assumed as reference in the West Bank model; [b] GS Center, where Gaza City is located, is assumed as reference in both the Palestine and Gaza Strip models.

The FCS results are quite different. According to OLS estimates (first column of Table 13), the quality of food consumption in Palestine seems to be negatively affected by the intensity of assistance.[23] However, in the fixed effects model, the interaction parameter is not significant. All variables whose coefficients are statistically significant show the same signs as in the poverty index models except for two cases: the dependency ratio and the household size. They both have a positive effect on FCS, possibly because a larger number of household members includes a sizeable share of children and elders calling for particularly dietary requirements and/or making the household more eligible for food aid targeting. Regional dummies are all negative vis-à-vis Central Gaza except for the North and Central West Bank. The latter two regions show non-significant coefficients, possibly explained by higher population density and more urban nature.

The West Bank and Gaza Strip models provide quite a different picture when considering the fixed effect model. The impact of assistance on FCS is positive and significant in the West Bank but it is not significant in the Gaza Strip. This may depend on the nature of the outcome variable. A higher FCS presupposes the availability and physical accessibility of a variety of food, a condition that may not have held in Gaza Strip because of the open armed conflict and strict blockade that occurred in 2014.

Keeping in mind that under these very specific conditions food security was pursued primarily through humanitarian assistance, we have to consider that in-kind food aid is based on food baskets containing only basic foodstuffs such as wheat flour, rice, pulses and vegetable oil. Therefore, in order to assess the impact of assistance on FCS via in-kind food aid, we disentangled the overall FCS in three additive components[24] and estimated the impact model per each FCS component (Table 14).

Doing so resulted in a slightly different picture. The intensity of assistance showed a positive impact of the two components provided via in-kind food assistance. The first component, which includes cereals, tubers, pulses, fruits and vegetables, is positive though significant only at p=90%. The second component, which includes oil and sugar, has a positive and significant impact at p=95%. Conversely, the component not included in the food aid basket, i.e. the meat and milk component, was not significant. This may be attributed in part to the nature of in-kind food assistance constituted of cereals, pulses and vegetable oil during the war in Gaza and in part to the low-income elasticity of these food categories as a source of low-cost calories and proteins. The less significant relationship found with reference to the first components can be explained by the dramatic drop in the availability of fruit and vegetables in the Gaza Strip as a result of the war.[25] This drop was only partially compensated by the in-kind food assistance of cereals and pulses. In conclusion, food security was ensured more in terms of the quantity of food provided than the

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reported that in practice up to 300 metres from the perimeter fence is considered by most farmers as a "no-go" area and up to 1,000 metres a "high risk" area" (OCHA, 2018: 5). This area is where most military operations take place.

[23] Higher FCS scores means in fact higher food quality as it measures food security in term of diet diversification.

[24] The three components and the relevant FCS weights are the following: fruits, vegetables, cereals, tubers and pulses (weights from 1 to 3); milk and meats (weight equal to 4); oil, sugar and others (weight equal to 0.5).

[25] Commercial food imports to the Gaza Strip cover a significant share of Gazan food needs. They stopped almost completely in the second half of 2014 because of the war and were partially offset by humanitarian imports providing food aid (Latino and Flämig, 2017).

Table 14. FCS components fixed effect regression models, Gaza Strip

	Total		Cereals, pulses, vegetables & fruit		Meat & milk		Oil & sugar	
	Coef.	Student 's t	Coef	Student's t	Coef	Student's t	Coef	Student's t
mass	-1.04	-5.44	-0.20	-3.31	-0.83	-5.01	-0.01	-0.97
ydum	-3.78	-3.28	0.23	0.62	-3.37	-3.46	-0.63	-8.12
massy	0.27	1.01	0.14	1.72	0.09	0.39	0.03	2.01
lhsize	5.11	5.76	1.39	5.18	3.37	4.27	0.35	5.77
dep_ratio	0.10	0.33	-0.06	-0.71	0.23	0.88	-0.07	-3.39
rat_emp	8.03	5.30	-0.15	-0.31	8.14	6.21	0.05	0.51
employed	-0.43	-1.02	0.24	1.87	-0.66	-1.75	-0.02	-0.53
R^2	0.07		0.02		0.07		0.06	

quality of diet during the war and following the conclusion of the hostility, at the height of the humanitarian crisis when interventions were primarily a matter of saving lives.

7. Conclusions

This paper contributes to the scanty literature on the impact of humanitarian assistance interventions and outcomes (Clarke *et al.*, 2014). It aims to answer a question that, to the best of our knowledge, has yet to be addressed: does assistance – broadly defined as any type of in-kind or cash transfer – improve the well-being of Palestinian households? To do so, we apply advanced econometric techniques and impact evaluation approaches widely advocated in the debate on aid effectiveness (cf. section 2.2). Specifically, we coupled the classical counterfactual framework of impact evaluation analysis with fixed effect econometric modelling using a difference-in-difference approach. This allowed us to treat sample selection bias. We also instrumented the fixed effect model to get rid of endogeneity where needed, such as in poverty models.

The main results are in line with existing literature (Ruel *et al.*, 2013). Assistance is indeed crucial to support the standards of living of Palestinians: both poverty and food insecurity would have been much higher without the massive assistance provided by the international community to Palestine. This result supports similar conclusions attained by recent studies on contexts marked by violent conflicts and food insecurity crises (Doocy and Tappis, 2016; Mercier *et al.*, 2017; Trachant *et al.*, 2018). We confirmed the key role played by assistance, specifically food aid, extending the evidence to a protracted crisis context such as Palestine.

The first policy implication is therefore that the international community should not keep disengaging from supporting Palestinian households. Over the last decade, overall assistance to Palestine shrank by two thirds since 2008. The international community should be aware that if assistance continues to diminish, the severely negative consequences on the ground will affect the wellbeing of these households. More generally, the positive impact of assistance on poverty reduction and food security established in this paper encourages renewed investment and further effort in enhancing aid effectiveness through better coordination of implementing actors and better design, targeting and delivery of assistance to the Palestinian people.

It is important to keep in mind that the average positive impact of assistance hides a lot of heterogeneity with marked differences on each outcome dimension (poverty, quantity of food consumed, diet diversity) and region (West Bank or Gaza Strip). In the case of poverty reduction, there is a clear positive impact of intensity of assistance for both Palestine as a whole and the West Bank. However, this relationship is not significant for the Gaza Strip, probably because of the July-August 2014 war that could have blurred the causal relationship between assistance and poverty reduction.

Assistance has a positive and significant impact on the amount of food consumed (proxied by HFIAS) in both regions, though the impact is much larger in the Gaza Strip than in the West Bank. This is thanks to massive in-kind food aid, food vouchers and cash interventions during and after the 2014 war that helped keep levels of food consumption at an acceptable level and restore household resilience (Brück *et al.*, 2018). In the case of diet diversity (proxied by the FCS), there is no significant impact of assistance for Palestine as a whole. The impact is however significantly positive for the West Bank but not for the Gaza Strip. When disentangling this last result according to main diet components, we see that the two components included in the food basket provided to households in need – cereals and pulses, and oil and sugar – have positively affected Gazan households. This is true despite the fact that in-kind food aid was only partially able to compensate for the dramatic drop in the availability of fruit and vegetables imports during and after the 2014 military escalation.

A second policy implication therefore relates to the importance of the composition of food baskets provided to a population in need in order to ensure a balanced diet (Webb *et al.*, 2014). This issue was raised in recent worldwide debates, specifically in Palestine where the food basket provided by UNRWA (OCHA, 2016) and by WFP (2017a and 2017b), the two most important implementing agencies, recently changed in order to provide more fortified and balanced food baskets. Careful consideration of the composition of food baskets is extremely important, especially when considering long-term consequences of a balanced diet to targeted households with children (Alderman *et al.*, 2006).

Our study presents some limits. Understanding why assistance determined the abovementioned outcomes would require more detailed information as well as an information-eliciting tool different from the one used by the SEFSec. Indeed, the SEFSec dataset, although quite informative on quantitative aspects of assistance to Palestinian households, is not able to open the black box of mechanisms that lead to these outcomes. Nor was it possible to analyze the effectiveness of different forms and sources of assistance, which affect the logics of intervention in a different manner. Addressing these topics would have required a larger and more detailed database supplemented by qualitative information, which we did not have.

Nevertheless, the SEFSec dataset may be further exploited to shed light on issues such as the spatial distribution of assistance. The dataset could even be used to conduct a finer analysis of the impact of different types of assistance on food security as soon as the third wave (carried out in late 2018) data is made available. Methodological speaking, a possible future improvement to consider would be to model the different impact of assistance on asset accumulation/decumulation or even on household expenditure, provided the data is of adequate quality.

8. References

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Full Research Article

Assessing Price Sensitivity of Forest Recreational Tourists in a Mountain Destination

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Abstract. Despite the large use of the travel cost method as estimation technique for the demand for forest recreation, information on price elasticity is only seldom reported. In this way, it is hard to understand if a large consumer surplus could be reflected in income opportunities for the local populations, because it is unknown whether the number of annual trips will decrease as a consequence of price changes. This is particularly relevant in remote rural areas, where few other opportunities for additional earnings are available. This contribution attempts to fill this gap, estimating price elasticities for two different specifications of the cost for travel; a first specification includes cost for travel only, while the second comprise on-site expenditures (such as food and accommodation). Data were collected by means of a questionnaire survey administrated to a sample of local visitors and analysed with a Poisson model. Results suggest that visitors have different sensitivities to distance travelled and to expenses locally sustained, the first being more elastic.

Keywords. Travel cost, forest recreation, price elasticity, Carpathians, rural development.

JEL codes. C21, D61, Q26.

1. 1. Introduction

A community-based destination may obtain several benefits from the development of an integrated tourism strategy, including the increase in work places, stimulus to local entrepreneurship and income generation (Hearne and Salinas, 2002). The development of nature-based forms of tourism may represent an effective strategy to balance the social, economic and environmental spheres of the sustainability (Bhuiyan *et al.*, 2016).

To understand the strengths and the potentialities of the territory as a tourist destination, decision makers should be aware of the benefits that people obtain from the local resources (Faccioli, 2011; Tempesta and Thiene, 2000). A typical technique used to evaluate recreational benefits is the travel cost model (TCM), which estimates consumer surplus (CS) per trip as a measure of the individual recreational benefit. CS represents

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the difference between what the individual actually pays for the trip and the maximum amount he/she was willing to pay for the same trip. A large CS suggests that the forest-tourism sector (e.g. local hotels and restaurants) and forest managers could increase prices and obtain higher remuneration, because the willingness to pay of the tourists is (on average) larger than the current cost (Hanley and Barbier, 2009). However, this information is not enough to design effective policies, because it does not consider the sensitivity of tourists to price changes, i.e. the price elasticity. When tourists are price-sensitive, higher prices could result in a decrease of the number of annual trips (or shorter trips), with no benefits for the local population (Levin and Milgrom, 2004). In the literature there are plenty of contributions dealing with the estimation of CS for forest recreation but elasticity is rarely estimated, so that the margin for additional earnings is uncertain. Despite recreational benefits have been broadly studied, information on price elasticity for forest-based recreation is rare in the literature. To the best of my knowledge, the paper by Simões *et al.* (2013), which illustrates a case study in Portugal, is the only recent contribution providing the estimation of price elasticity. While this study is interesting for Mediterranean forests, results could be hardly generalized to other areas, for example mountain forests and northern European forests, because they are different in terms of tourists profile and tree species composition.

In this paper, I expand the study of price elasticity for forest-based recreation, using a mountain area as case study and two different specifications of the cost for travel. In the first specification, the travel cost depends only on the distance travelled, while in the second all the self-reported costs sustained for the trip are included. In this way, it is possible to distinguish between sensitivity to distance travelled and to expenses inside the location. Elasticity informs about how price could be used to increase revenues from a single tourist without the risk to decrease the total number of visitors. Therefore, this study is useful not only to raise the question on the importance of elasticity as a policy measure to consider but also for managers and local entrepreneurs to develop an effective management of the destination.

The study area is the Beskid Zywiecki range, a mountainous area in the southern Poland, located in the Silesian Voivodeship. The area is in the Carpathians, the highest mountain chain of the central Europe, comprehending Poland, Ukraine, Romania, Slovakia and the Czech Republic. Understanding the tourists' demand, its elasticity and the benefits that people obtain from visiting the Beskid may contribute in raising the awareness of the role that tourism may play for local development, stimulating an integrated tourism strategy (Mirani and Farahani 2015).

2. Materials and Methods

2.1 The Study Area

Beskid is the traditional name that it is used to identify some portions of the Carpathian Mountains. The Beskid Zywiecki range is a territory of about 60.000 ha of the Silesian region (southern Poland) composed by three forest districts: Jeleśnia, Ujsoły and Węgierska Górka (49°23'42"–49°38'54"N; 18°58'29"–19°27'16"E). The area includes 31,000 ha of Landscape Park, out of which around 30,000 are included in the Natura 2000 network, and the Babia Gora biosphere reserve is included in the UNESCO natural heritage list. Beskid Zywiecki has a vast forested territory, forests represent the main natural ecosystem and tourists use to visit the area for nature-based activities. The main tourists´ activities are trekking, sightseeing and sport practising but surrounding villages include other attractions such as churches and castles (i.e. Żywiec castle and Sucha Beskidzka).

2.2 Data

A questionnaire survey was implemented to collect the necessary information for the TCM. Questionnaires were hand-delivered in some strategic places within the destination (hotels, restaurant and main places of interest) in summertime with the help of local workers and forest managers and collected after one month. The sample is unlikely to be perfectly random, because completing the questionnaire is potentially subject to selection bias. The outcome could be described as convenience sampling, which is a limitation that must be considered when interpreting the results. Nonetheless, data does provide policy-relevant information and insights on the local forest use. The questionnaire is part of a broader research and it was divided in three section: section A contained questions about tourist characteristics, which was used to collect data for the TCM and for general features of the tourists. Section B was designed in order to investigate people´s preferences about a series of environmental issues, including mixed forests and ecosystem services. Section C cellected socio-economic characteristics and it was included at the end of the questionnaire, in order to reduce fatigue effects in compiling the most important questions. The present paper discusses the results of section A, interacted with socio-demographic variables obtained in section C. In order to collect data for the TCM, people were asked to state their place of origin and the distance from the destination. The questionnaire included also questions on the main holiday motivations.

The number of collected questionnaires was 145, out of which 142 were compiled enough to allow the application of the TCM. The size of our sample is small but it is comparable to other studies, as travel cost model estimation is less data demanding compared to stated preference surveys (Champ *et al.*, 2003). As an example, Curtis (2002) surveyed a sample of 118 anglers for a travel cost estimation of salmon angling for the whole Ireland. Englin *et al.* (1997) used a sample of 120 respondents for the estimation of the recreational benefits of four American states (New York, Vermont, Maine and New Hampshire).

Table 1 shows the descriptive statistics of the sample. Surveyed tourists were 55% females and 45% males. Respondents were mostly below 50 years old with a relatively high education, in fact, more than 50% of the sample had at least a bachelor degree. Despite the high level of education, which is usually connected with an income higher than the average, most of the people declared a low-income. This apparent odd result may be due to the fact that most of the people are young, so they are still student or at their first job experience, as the age structure of the sample shows. The mean travel cost for reaching the destination was assessed to be 40.8 PLN, while the average daily expenditure for additional goods and services (i.e. meals, accommodation) 128.5 PLN.

The average number of night overstay derived from the sample has been proved to be 5.5 per trip. Through the questionnaire, it was possible to collect information regarding the main holiday motivation of the tourists visiting Beskid Zywiecki. The questionnaire

Table 1. Socio-demographic characteristics of the respondents.

Category	Profile	N	%	Mean	Median	St. Dev.	Min	Max
Income (PLN)	0 -1500	39	29.9	2.74	2	1.77	1	7
	1500-2500	42	30					
	2500-3500	20	14.3					
	3500-4500	19	13.6					
	4500-5500	6	4.3					
	5500-6500	3	2.1					
	6500+	11	7.9					
Age	0 - 30	47	33.6	2.38	2	1.32	1	5
	30-40	29	20.7					
	40-50	33	23.6					
	50-60	22	15.7					
	60+	9	6.4					
Education	Primary	9	6.4	2.85	3	1.08	1	5
	High sc.	60	42.9					
	Bachelor	21	15					
	Master	43	30.7					
	PhD	7	5.0					
Gender	Male	63	45.0	0.55	1	0.5	0	1
	Female	77	55.0					
Household		140		3.40	3	1.75	0	10

contained a list of six typical holiday motivation in mountain areas (Kozak, 2002) with the possibility to add other options. Two people indicated working as a motivation for their overstay, so they were excluded from the sample. Each respondent could mark more than one motivation. Table 2 shows that the most cited activity is walking in the mountains (59.3 % of the sample), followed by ecotourism and visiting relatives. This result may indicate that the main source of recreation is nature, in particular forests, which are the main natural element, with its biodiversity.

Table 2. Holiday motivation declared by respondents.

Holiday Motivation	Frequency	%
Visiting relatives	30	21.4
Museums	7	5
Walking	83	59.3
Sport practising	15	10.7
Ecotourism	40	13.57
Sightseeing	19	5.7

2.3 The Travel Cost Method

The TCM is an evaluation technique, frequently used to value the recreational benefit of particular site (Herath and Kennedy, 2004; Hill *et al.*, 2014), proposed by Harold Hotelling for the first time in 1947 (H. Hotelling, 1949) and then refined by Clawson and Knetsch (Clawson M. and Knetsch J. L., 1966). The method assumes that the costs sustained by visitors for visiting the site may approximate the value of their recreational experience (Willis and Garrod, 1991). Another basic idea of the method is that people are travel cost-sensitive, meaning that the higher is the cost (and the longer is the distance travelled) and the smaller is the number of trips they make. The demand function is integrated with socio-economic characteristics and sometimes with environmental and site-specific considerations. The resulting demand curve models the number of trips to the recreational site as a function of the cost sustained for the travel and other characteristics:

$$Y_i = f[(TC_i, I_i, h_i(D_i, V_i, S_i)]$$

Where Y_i is the number of trips of the individual i, TC_i is the cost that the individual i per round-trip, I_i is the individual income while h_i is a vector of visitor-specific characteristics. *h*i may include information about alternative sites (S_i), study site (V_i) and socio-demographic characteristics (D_i). The dependent variables I used in this paper are (1) the number of trips done in the last year and (2) the number of trips in the last 5 years. These take only non-negative values, so count data models are the most common approaches for the analysis (Hellerstein, 1991), in particular the Poisson and negative binomial (NB) regressions.

The theoretical framework for the use of the Poisson model for modelling recreational demand was provided by Hellerstein and Mandelsohn (Hellerstein and Mendelsohn, 1993). The authors state that the choice whether visiting or not a site can be described with a binomial distribution, converging to a Poisson as the number of trips increase. The Poisson distribution for the number of trips y is

$$\Pr[Y=y] = \frac{e^{-\mu} \bullet \mu^{y}}{y!} \quad Y= 1,2,\ldots.n$$

Where μ is the rate parameter. The Poisson distribution can be used in regression by explicating the relation between the mean parameter μ and the vector of *x* regressors. The usual approach is to use an exponential mean parametrization:

$$\mu_i=\exp(x'\beta) \qquad i= 1,2\ldots,n$$

Where x is the matrix of regressors and β the coefficients. The Poisson regression is estimated through the maximum likelihood method, as all generalized linear models. The Poisson model is equi-dispersed, meaning that the mean is equal to the variance. In many cases data are over-dispersed, i.e. the variance is larger than the mean. When data are over-dispersed and the sample is truncated the Poisson model returns inconsistent estimates and a NB model should be used, as it adds an extra parameter controlling for overdispersion. The presence of overdispersion was tested with a log-likelihood ratio test that failed to reject the hypothesis of over-dispersion returning a non-significant p-value. The suitability of the Poisson model for this case was also enforced when a NB model was tested, as the α parameter was not significant. For this reason, the following analyses continued with a Poisson model.

When data are collected on-site, there are two other characteristics of the sample that should be considered, truncation and endogenous stratification, for which both Poisson and Nb models can be corrected (Shaw, 1988). Truncation occurs because people with zero trips are not surveyed. Endogenous stratification is instead related to the higher probability of sampling frequent visitors compared to tourists with only few trips in the timeframe. Englin and Shonkwiler (1995) showed that a Poisson model can be corrected for both truncation and endogenous stratification simply replacing the response variable *y* with *y-1*. The model was all estimated using STATA 12 (StataCorp 2011). After the estimation of the econometric model, CS and elasticities can be derived. The CS per trip is estimated with the following formula:

$$CS = \frac{-1}{\beta_{tc}}$$

Where β_{tc} is the parameter associated with the travel cost variable. Elasticity of the demand to the cost of travel (e_p) is computed in this way:

$$e_p = \frac{\partial E(\mu)}{\partial X_{tc}} \frac{X_{tc}}{} = \beta_{tc} X_{tc}$$

Where X_{tc} is the travel cost variable and μ the mean of the distribution.

Table 3 describes more in details the variables considered, together with the description and the expected effects. The fuel cost per round-trip was estimated by asking respondents the travelled distance from their starting point to the place where the interview took place. Then the travel distance (in km) was multiplied per a cost per km of 0.4 PLN, which is the average cost per km available in the official statistics. The number of days spent in the destination and socio-economic variables, including gender, education, occupation, income, education and number of people in the household represent the other covariates and were also collected through the questionnaires (section C).

Table 3. List of the explanatory variables used in the travel cost.

Variable	Code	Description	Expected effect*
Tc	PLN/Trip	(Fuel) cost per round-trip	-
Tc_complete	PLN/Trip	Average cost of one day including food, accommodation and other expenses	-
N_days	Integer number	Average Number of days per each trip	-
Income	Classes from 1 to 7	1 represent the poorest class, 7 the reachest	+
Gender	0 1	Male female	-
Age	1 0	Older than 60 Otherwise	+/-
Education	Classes from 1 to 6	1 is elementary education, 6 is for PhD holders	+
household	Integer number	Number of people in the household	+
Employed	1 0	Full-employed Otherwise	-

* Expected relationship between the explanatory variables and the number of individual trips.

3. Results and discussions

The TCM results are summarized in Table 4 and Table 5, showing the econometric model and the welfare analysis, respectively. The cost of travelling towards the destination has a negative sign as expected and it is highly significant (p value lower that 0.001) in all the specified models, indicating that the number of visits decrease as the distance (and related cost) increase. The coefficient for *TC_expense* is also negative.

The number of days of each trip has a negative sign suggesting that people making longer trips have fewer annual visits. Age is also negatively connected with the likelihood of visiting the Zywiec area, so young people contribute more to tourism and recreational activities. The income variable has a positive coefficient, therefore annual visits increases with higher incomes. Income shows a very high significance (1% confidence level), which is not common in TCM studies (Martínez-Espiñeira and Amoako-Tuffour, 2008). The gender variable has a negative sign; since the male tourists were coded as 0 and females as

Table 4. Results of the different Poisson.

	Poisson
Tc	-0.0213***
	(0.00205)
Tc_complete	-0.000460**
	(0.000192)
N_days	-0.0164**
	(0.00769)
Age60more	-0.250**
	(0.119)
Gender	-0.542***
	(0.0929)
Employed	-0.266***
	(0.101)
Education	0.161***
	(0.0519)
Household	0.0630**
	(0.0299)
Income	0.0610***
	(0.0131)
Constant	1.517***
	(0.197)
Observations	142
AIC	974.3
BIC	1003.8
LL	-477.13

Standard errors in parentheses
* *P<0.10* ** p<0.05 *** p<0.01

Table 5. Marginal consumer surplus and elasticity derived from the different models.

Model	Tc	Tc_complete
CS per visit (PLZ)	47	2173
CS per year (PLZ)	216	9996
CS per visit (€)	10	480
CS per year (€)	46	2208
elasticity	-.12	-.90

1, the coefficient states that males are more likely to visit the Beskid Zywiecki range. People in full employment are less likely to visit the study area, maybe because of less availability of time. Personal education is another important variable for describing tourism in the Beskid Zywiecki range, it has a positive and significant coefficient. Tourists seem to be more willing to visit as their education increase. Finally, the household variable has positive relationship with the number of visits, suggesting that larger household are more likely to visit. A possible explanation for this result could be that the Beskid is a destination for families with children.

We now move to the conventional welfare and policy measure, i.e. CS and elasticity, that are calculated from the coefficients of the cost variables. It is important to remember that, in order to extrapolate the welfare measures from truncated models, it has to be assumed that non-visitors have the same demand function as the visitors (Hellerstein, 1991). Welfare measures are summarized in 5. The Polish currency (PLZ) was converted into € using an average exchange rate of 4.50 PLZ per Euro for 2014 (i.e. when the survey was undertaken). The CS per visit using only the cost of travel (labelled 'Tc' in Table 5) is what is typically shown in TCM studies and it is estimated to be 10€ per visit. This result is comparable to other studies. For example, Grilli *et al.* (2014) investigated recreation in mountain areas through a meta-analysis of studies, achieving a mean value of about 11 € per visit and an upper bound of 112€ per visit. The value is also lower than the one found by Getzner in the Tatra Mountains (Getzner, 2010), which represent the most important destination within the Carpathians and therefore with a higher recreational potential. The CS per year is calculated multiplying the CS per one visit by the average number of trips of the sample, which is 4.6 per year.

Calculating CS using the total expenses sustained in the destination is less common in the forest recreation literature while it is more popular in the study of consumptive activities, such as fishing or hunting. This study assessed a CS per visit of about 480€ per day, which is comparable to that of fishing (Curtis, 2002; Curtis and Breen, 2017) and lower than natural park tourism in the United States (Martínez-Espiñeira and Amoako-Tuffour, 2008).

In addition to CS, what is interesting to notice is the elasticity of the demand. The demand appears to be inelastic in the first model (-0.12), suggesting that the number of visit is expected to make only minor variations when the cost for travel (mainly related to fuel) changes. At a practical level an increase of 10% of the average cost for travel would cause an average decrease of 0.05 trips per year. If the cost for travel doubles the number of annual trips decreases by only 0.55 (one trip less every two years).

When *in-situ* expenses are also considered in the computation of the travel cost, the estimated elasticity becomes -.90. According to the conventional definition the demand is still considered inelastic but it is closer to one, which is the conventional threshold for the price elasticity of the demand to become elastic. This means that a 10% increase in the average cost of the trip causes a decrease of trips of 0.8, almost one per year. In the remote case that the average cost of travel doubles, people would do 4 trip less per year, i.e. they would not visit anymore.

3.1 Implications

Although information derived from a convenience sampling should be read with care, this study provides useful information to policy-makers. Mountain villages all over the world are facing problems connected with depopulation and the necessity to assure sources of income for the inhabitants. Valorising the local natural resources for tourism may be an effective strategy to allow additional income generation. Local communities might obtain larger profit from tourism (in terms of expenditures locally sustained for food, accommodation, technical equipment etc…) either increasing the number of annual visitors or increasing average prices. With respect to the first option, the close Silesian district is one of the most populated areas in Poland and represents an interesting basin of potential visitors, which could be reached with more intense marketing activities (Vogt *et al.*, 2018). The recent literature on tourism planning suggests that tourism development is perceived positively by local communities (Coccossis, 2017; Muresan *et al.*, 2016) but raising the number of tourists is likely to increase relevant environmental impacts (Lake *et al.*, 2017; McCombes *et al.*, 2015), therefore visitor management is fundamental to preserve the environment (Gios and Clauser, 2009).

The second option to increase local incomes is to raise local prices. The high CS suggests that visitors would be willing to pay more than current amounts for a single visit because they obtain a large benefit from visiting Beskid Zywiecki. On the other hand, the elastic demand indicates that the number of annual trips could be lower if prices will be too high. Therefore, the net effect of raising prices will be uncertain. Such evidences suggest that there is not a unique strategy to develop the territory and decision makers should obtain as much information as possible to undertake an effective planning.

4. Conclusions

Forest recreation is a valuable activity and the economic relevance should be carefully monitored. In this paper an investigation of recreational values of mountain forests was presented using a case study located in the Polish Carpathians, with a focus on price elasticity because this policy measure is not often considered. A travel cost model based on the Poisson regression has been estimated using two different cost variables, the first capturing only the cost of travel and the second including also the cost for food and accommodation incurred on site. The estimated consumer surplus of 480€ suggested that there is space for local operators to increase prices and revenues, however the estimated price elasticity of -.90 suggests that visitors are sensitive to local expenditures and therefore local prices should be fixed with care, because they may cause a decrease in the number of annual visitors. There is a trade-off between the number of visitors and the expenditures they sustain in the territory, therefore local managers wishing to obtain higher revenues can hardly increase both and should carefully evaluate their preferred management strategy.

Being aware that a single case study is not enough to draw general conclusions, this study would like to raise the issue and encourage other researchers to further investigate price sensitivity in future recreational studies.

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Full Research Article

Estimating a Dual Value Function as a Meta-Model of a Detailed Dynamic Mathematical Programming Model

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Abstract. Mathematical programming (MP) is a widespread approach to depict production and investment decisions of agents in agent-based models (ABM) related to agriculture. However, introducing dynamics and indivisibilities in MP models renders their solution computing time intensive. We present a meta-modeling approach as an alternative to directly integrating MP in an ABM. Specifically, we estimate a dual symmetric normalized quadratic (SNQ) value function from a set of MP solutions. The approach allows us to depict relationships between key attributes, like the farm endowment with (quasi-) fixed factors and discounted farm household incomes, without modeling the technology in detail. The estimated functions are integrated in the ABM to derive agents' decisions. The meta-modeling approach relaxes computational restrictions such that spatial interactions in large regions can be simulated improving our understanding of structural change in agriculture. It can also be used to extrapolate to farming populations where data availability might be restricted.

Keywords. Mathematical programming, Mixed Integer Program, meta-model, duality, symmetric normalized quadratic value function, agent-based modeling.

JEL codes. Q15, C61, C63.

1. Introduction

Agent-based modeling is a popular approach to simulate phenomena depending on spatial interactions between farmers (Berger 2001; Britz 2013a; Huber *et al.* 2018). It allows integrating behavioral rules that differ from standard micro-economic assumptions such as full information and full rationality (Bonabeau 2002; Nolan 2009). These features render agent-based models (ABMs) particularly suited to investigate the complex dynamic processes underlying structural change in agriculture (Zimmermann *et al.* 2009).

ABMs rapidly become complex and computing intensive if behavior of agents is modeled in detail (Zimmermann *et al.* 2009). This is especially true for ABMs that, first, use mathematical programming (MP) to derive agents' behavior in the ABM and that, second, explicitly model land markets as key driver of structural change in agriculture (Bal-

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mann 1999). In this type of ABMs, decision making of farmers regarding production and investment quantities or willingness to pay for (quasi-) fixed resources is typically (partly) derived from (discounted) profits or household incomes[1], as well as from marginal values of (quasi-) fixed resources simulated by MP (Schreinemachers and Berger 2011; Happe *et al.* 2006). Accordingly, a MP model has to be solved at least once for each agent and in each time step of the ABM. To represent realistically the decision space of agents, especially when considering investments, MP models require a large set of constraints as well as binary and integer variables (Mixed Integer Program, MIP). This can result in model set-ups with several ten thousand equations and variables, of which several hundreds are binary or integer variables (Britz *et al.* 2016). As a consequence, running an ABM on large farming populations is very resource demanding if each agent's behavior is derived from solving a large MIP.

MP solutions serve as inputs for different elements of ABMs focusing on agricultural structural change. Farm household income drives exit decision of farmers; and marginal returns to land (or other factors distributed by auctions) determine the bids of agents in simulated markets. As a consequence, income and marginal returns to land determine which farms grow, shrink or exit in the ABM and are, therefore, key drivers of dynamic processes in ABMs (Balmann 1999). In particular, simulation of land auctions is computationally challenging. Bids have to be calculated for each farmer and each plot of land that is available for rent at each time step, which can require solving a MP model for each combination of plot and farmer. Such ABM applications require efficient sampling schemes and sufficient computing power, especially if a whole agricultural region with many agents and a long time horizon should be investigated (Troost and Berger 2016). Even with increasing computational power such as using computing cluster and efficient MIP algorithms solving in parallel (e.g. Britz 2013b; Troost and Berger 2016) direct implementation of large MP models in an ABM results in high computing intensity.

The tension between computing needs and increased detail and coverage is a long-standing problem in the scientific and engineering simulation domain despite the tremendous increase in computer power and algorithmic progress. It persists since increased data availability, using sensitivity analysis and growing model sizes, by e.g. integrating more interactions between the agents, drive up computing needs. Indeed, the higher computing power itself invites researchers to increase model size and complexity to overcome shortcomings in previous set-ups. This can also be observed for agricultural ABMs using MP models (e.g. Arsenault *et al.* 2012; Brown *et al.* 2016; Kellermann *et al.* 2008; Lobianco and Esposti 2010; Polhill *et al.* 2007; Schreinemachers and Berger 2011; Zimmermann *et al.* 2015). They are now solved with far more agents, integrate different types of agents and/or different types of market interactions, or they use MP models which are harder to solve. Furthermore, large-scale sensitivity to address model uncertainty has become widespread. Thus, to keep computing time at bay, agricultural ABMs using MP models still face restrictions with regard to the number of agents and/or to the design of the MP

[1] In the following, we only refer to "income" for the sake of readability. Dependent on the model set-up, a MP model derives profit rather than household income if off-farm labor or other non-agricultural activities are not included. In the MP model we use, farmers also generate income from non-agricultural sources. The term "discounted" applies to dynamic settings where MP models are solved for several years. In this case, yearly profits or incomes are discounted.

approach. Reflecting that MIP problems are NP-hard to solve[2], MP models are set-up without dynamics, with no or a decreased number of binaries or integers, or with an overall reduced number of constraints and variables.

To overcome the need to sacrifice detail in a simulation model in favor of speed, meta-modeling strategies that require less computational power have been developed (Meckesheimer *et al.* 2002). They provide a simple mathematical approximation of the input/output relations in the underlying simulation model (Kleijnen 2018; Kleijnen and Sargent 2000; Meckesheimer *et al.* 2002; Pierreval 1996), drawing on statistical approaches such as (polynomial) regression models, splines or neural networks (Kleijnen and Sargent 2000). Their aim can be threefold: first, to improve the understanding of the behavior of the simulation model and the problem entity; second, to optimize the model with respect to the determination of the input set; and third, to make predictions of the model's simulation behavior (Bouzaher *et al.* 1993; Kleijnen 1979; Kleijnen 2005; Kleijnen and Sargent 2000). In the latter case, the meta-model is run instead of the simulation model itself, mainly to reduce computing needs (Kleijnen and Sargent 2000; Meckesheimer *et al.* 2001; Meckesheimer *et al.* 2002).

The objective of this paper is to develop a dual value function as a meta-model of a complex MP model motivated by the opportunity to reduce computational limitations of simulations with ABMs. The meta-model also allows to extrapolate to larger farming populations where the necessary detailed information on endowments such as structures and machines, as well as costs, labor and investment needs to set-up a MP model, is not available for each agent. Furthermore, setting-up and calibrating MP models to yield realistic solution behavior is a time consuming process which can be only partially automatized (see Troost and Berger 2016). The two aims of reducing computing needs and covering a larger population are therefore interrelated.

Our approach integrates a meta-model of a MP model in an ABM to compute optimal production and investment quantities, related discounted income and marginal values of (quasi-) fixed production factors. We, first, solve a suitable number of farm optimization problems with the MP model to obtain a farming population with individual production plans. We, next, estimate a meta-model from the MP results and subsequently integrate the estimates in the ABM. Specifically, we estimate a dual symmetric normalized quadratic (SNQ) value function which simulates discounted farm household income, input and output (i.e. netput) quantities and marginal values. As in the underlying MP model, the meta-model reflects production and investment decisions under maximization of discounted income at given prices and endowments, providing results under full rationality. However, simulated values can also be used to depict agent behavior that deviates from this assumption. To give an example, instead of using the marginal values of land, the average discounted income per ha of land can be used to define the marginal willingness to pay for an additional plot of land.

The structure of the paper is as follows. First, we present the general methodology to develop a meta-model of a MP model to be integrated in an ABM (chapter 2). In chapter 3, we apply the proposed method to a specific setting in order to precisely describe

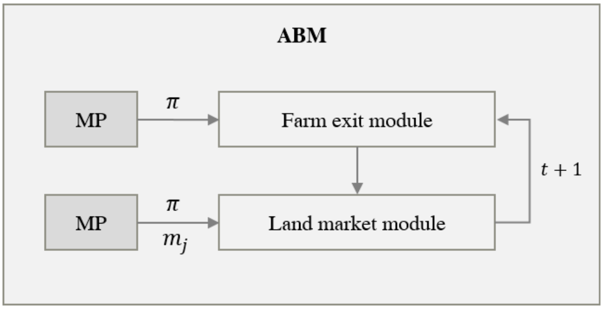
[2] "NP" stands for non-deterministic polynominal time algorithm. NP-hard means that so far, no algorithm has been found which could solve MIP problems in polynominal time. Clearly, the actual solution time depends on problem size and structure, the solver and hardware used.

our methodological approach. Chapters 4 and 5 present and discuss the estimation results before we briefly conclude in chapter 6.

2. General methodology

Many ABMs focusing on structural change in agriculture directly integrate a MP model in the model set-up (Fig 1)[3]. The MP model, solved for each farmer and at each time step, delivers income, input quantities bought and output quantities sold, as well as marginal values to (quasi-) fixed factors such as land and labor. Often, simulated incomes drive farm exit decisions in ABMs. In land market auctions, marginal returns to land can be used to determine the agents' willingness to pay for an additional plot. Aggregated quantities of inputs and outputs over the farming population might be used to define price feedbacks in the ABM, such that aggregated macro-level phenomena have an impact on agents' behavior on the micro-level (Chen and Liao 2005).

Figure 1. Classical set-up of an ABM integrating MP.



Note: π = (discounted) profit or income, m_j = marginal returns to (quasi-) fixed factors, t = yearly time steps of ABM.

Computing time restrictions for solving an instance of the MP model limit the complexity of the MP approach and/or the number of agents. Therefore, we develop a meta-model of the MP model which we integrate in the ABM. The meta-model delivers the same information as the MP model, but much faster by approximating the behavior of the MP model based on an estimated dual value function. The estimated dual value function mimics the simulation behavior of the MP model. Using the same inputs as the MP model, i.e. prices and endowments of each farm in the population, it generates outputs (income, netput quantities, marginal returns to (quasi-) fixed factors) that are very close to those simulated by the MP model. The MP model has to be solved only once for the whole farming population. Production quantities, income and marginal values of each

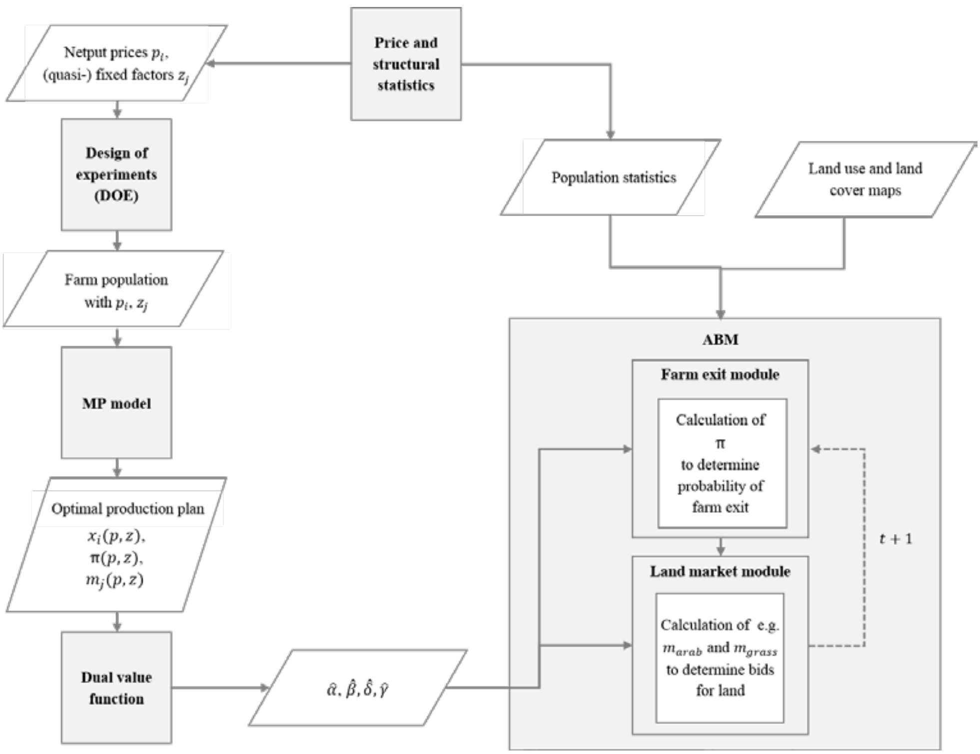
[3] In this and subsequent figures of ABMs in this paper, only the two modules of farm exit and land market are presented. Obviously, an ABM can include other and/or further modules to which our approach can also be applied if agent's decision making is based on MP.

farmer are updated in the ABM using the estimates of the dual value function. In the classical approach, the MP model has to be solved in each simulation period to derive production quantities, income and marginal values.

The advantage of estimating a dual value function over independent regressions of variables of interest is that the value function represents income maximizing behavior just like the MP. According to duality theory, the dual function depicts the optimal frontier, i.e. income maximizing netputs at given prices and limiting production factors. Thus, it maintains microeconomic consistency and indirectly comprises the information on the production feasibility set (Diewert 1971; Sidhu and Baanante 1981; Thijssen 1992). While in the classical approach, the technology of agricultural production is directly integrated in the ABM through the MP model; in the meta-modeling approach, it is represented in its dual form by the estimates of the value function.

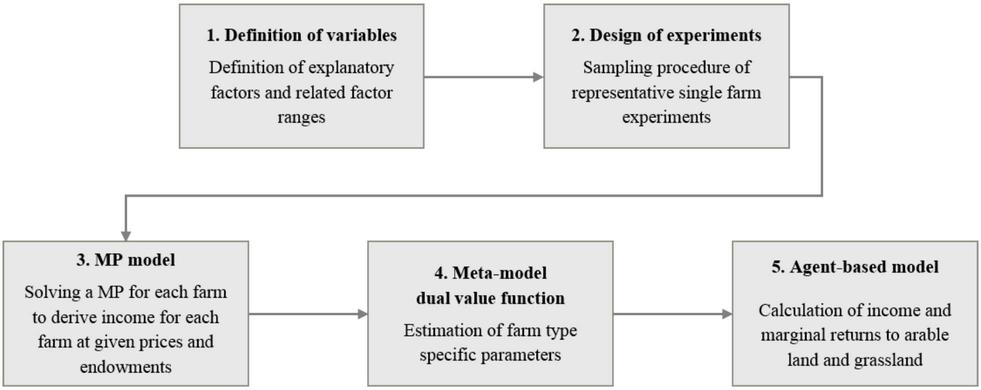
The overall modeling approach is depicted in Figure 2; the steps to take in the modeling approach are presented in Figure 3.

Figure 2. Meta-modeling approach.



Note: p_i = prices of inputs and outputs, z_j = farm's endowments with (quasi-) fixed factors, x_i = quantities of inputs bought and outputs sold, π = (discounted) profit or income, m_j = marginal returns to (quasi-) fixed factors, m_{arab} = marginal returns to arable land, m_{grass} = marginal returns to grassland, $\hat{\alpha}, \hat{\beta}, \hat{\delta}, \hat{\gamma}$ = estimated coefficients of value function, t = yearly time steps of ABM.

Figure 3. Steps in the meta-modeling approach.



First, the most important explanatory factors, which differentiate the farmers in the region to be investigated, and their factor ranges need to be defined based on price and structural statistics, e.g. the number of farms of different farm types in a region, the distribution of farm sizes in a region etc. Second, a suitable observation sample has to be defined using design of experiments (DOE) to cover the farming population. Third, in comparison to the classical approach (Figure 1), a MP model designed to capture important interactions at farm level is solved for each observation of the farming population once outside of the ABM before the start of the ABM-simulation. This yields the optimal production plan for each farmer, i.e. a dataset of optimal investment and production quantities, related farm household income and marginal returns to (quasi-) fixed factors. Fourth, these solutions are used to estimate a dual value function that becomes the meta-model of the MP model. Fifth, the function along with estimated coefficients are integrated into the ABM and used for calculating income and marginal returns to (quasi-) fixed factors for each agent at each time step.

3. Application

We apply the suggested meta-modeling approach to the MP model FARMDYN, the ABM ABMSim and the German region of North Rhine-Westphalia (NRW). NRW encompasses 3.4 million hectares of which 1.4 million hectares are agricultural land managed by 33,700 farms. The agricultural structure is dominated by livestock farming with 67 % of the farms holding cattle and/or pigs. NRW is characterized by high agricultural productivity and strong economic pressure on the land market with a rental share above 50% (IT.NRW 2019). Therefore, we assume that agents act in a (bounded) rational way, i.e. they optimize under limited information. Furthermore, we represent land rental markets in the ABM as auctions.

To investigate structural change in NRW in an ABM, the around 34,000 farms need to be depicted as agents. In an approach integrating a MP model in the ABM, the MP model must be solved at least once in any year of the simulation horizon for each farmer. In our setting, the MIP optimization problem for a single farm comprises roughly 20,000 equations with 30,000 variables including 3,000 binary or integer decision variables. Solving 34,000 of these MIPs takes several days. Even if the MP model would be less complex, the computing time would be still too high to allow investigations of structural change of the whole region over several years. With the meta-modeling approach, however, the several ten thousand optimization problems can be solved within a couple of minutes which allows us to solve an ABM over 10 years for the whole region of NRW within 15 minutes.

In the following, we present the meta-modeling approach along the five steps as depicted in Figure 3.

3.1 Generating the farm sample (Steps 1 and 2)

Observation samples for farms of different specializations (arable cropping, dairy, pig fattening, cattle fattening, mixed) are generated considering variations in (1) input and output prices, (2) endowment with (quasi-) fixed factors and (3), where appropriate, factors describing the technology such as the milk yield per cow. The factor ranges are chosen to capture the possible minimum and maximum values found in the farming population according to statistical data from the Association for Technology and Structures in Agriculture (KTBL) (KTBL 2016) and regional data of NRW (IT.NRW 2019).

Design of experiments (DOE) generates for each farm specialization a sample of farms that differ in initial conditions and other attributes. Initial conditions are, among others, available family labor, capital stock (stables, machinery and storage facilities), arable land and grassland owned by the farm. Other attributes are input and output prices that describe the farm's market environment as well as yield potentials and household expenditures (Britz *et al.* 2016).

To make the solution procedure more efficient, we make sure that only plausible combinations of factor ranges are generated. Unrealistic set-ups such as a farm with 250 cows, 10 ha and 0.25 labor units are likely to either lead to infeasibilities, i.e. to a loss of observations, or to unrealistically high or low marginal returns. Therefore, instead of drawing independent factor values from absolute factor ranges, we define for each farm branch one key attribute, e.g. total farm size in hectares for arable farms or dairy herd size for dairy farms. Factor ranges of further attributes are defined relative to the key attribute and from there mapped into absolute values. As an example, for the farm branch dairy, the farm's endowment with arable land and grassland is defined by its individual amount of hectares of arable and grassland per number of cows. The absolute amount of arable and grassland is then defined by multiplying sampled number of cows with sampled hectares of arable and grassland per number of cows.

In order to consider many factors and decrease computing time, we construct our sample based on Latin-hypercube sampling (LHS) as an efficient quasi-random sampling procedure. LHS is a space filling random sampling design that distributes the randomized factor level combinations smoothly over the range of factor level permutations (Iman and Conover 1980; McKay *et al.* 1979). Specifically, we apply the LHS package of R by Carnell (2016), assuming a uniform distribution over each considered factor.

After steps 1 and 2, we have a farming population with individual endowments with e.g. arable land, grassland and labor units, as well as prices of netputs that farmers face, reflecting the farming population and prices in the region under investigation.

3.2 Description of the MP model

The MP model FARMDYN (Britz *et al.* 2016), that we use for our application, simulates economic optimal production and investment decisions, assuming a fully informed, fully rational and profit maximizing farmer[4]. It considers farm profits including subsidies plus potential earnings from off-farm work, given constraints such as a detailed depiction of the production feasibility set of the farm, the maximum willingness to work on the farm or off-farm, liquidity or restrictions relating to the Common Agricultural Policy and German environmental laws. FARMDYN can be run in either comparative-static or dynamic mode with a finite planning horizon.

Decisions of investments and labor supply are modeled as integer variables to consider indivisibilities and to reflect returns to scale, for instance relating to stable sizes or labor needs for the management of farm branches. As an example, the MIP assumes that the farm can work at higher wages for 20 or 40 hours a week and/or to supply a low amount of off-farm labor at the legal minimum wage. Different farming systems can be simulated (arable, dairy, beef, pig fattening and biogas plants) and combined to depict diversified farms.

FARMDYN currently reflects German conditions drawing on technological and economic data from KTBL (Britz *et al.* 2016; KTBL 2016). Originally developed to derive marginal abatement cost functions in German dairy farming under differently detailed emission accounting schemes (Lengers *et al.* 2013), it was subsequently extended by a detailed description of pig farms (Garbert 2013), arable farming (Remble *et al.* 2013) and biogas plants (Schäfer 2014; Schäfer *et al.* 2017). FARMDYN is a bottom-up model. It is evaluated by means of its gross margins. Gross margins as simulation results of typical farms of a particular region (e.g. taken from structural data of North Rhine-Westphalia, IT.NRW 2019) are compared with data provided by KTBL (KTBL 2016).

FARMDYN is realized in GAMS and solved by the industry MIP solver CPLEX 12.6 (Britz *et al.* 2016), in our application on a 44 core computing server profiting from parallel processing in CPLEX. Furthermore, efficient solution strategies are implemented in FARMDYN such as parallel computing on multiple cores and the reduction of the solution space of the MIP by, first, solving a relaxed MIP (RMIP). A Graphical User Interface based on GGIG (GAMS Graphical Interface Generator, Britz 2014) allows to steer model runs and to exploit results (Britz *et al.* 2016). A detailed description of the model can be found in the FARMDYN model documentation (see Britz *et al.* 2016).

3.2.1 MP model run (Step 3)

As third step in our meta-modeling approach, we use FARMDYN to derive optimal farm household income, netput quantities and marginal returns to (quasi-) fixed factors for each farmer in the farming population sampled in the previous step.

We run FARMDYN in dynamic mode. In the dynamic set-up, optimal decisions are simultaneously determined at each point in time based on the current state of the system, reflecting the Principle of Optimality by Bellman (Bellman 1954). A value function dis-

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[4] A dynamic-stochastic variant of the model is also available which can capture risk behavior based on different approaches to which the approach could also be applied.

counts the incomes that are simulated at each point in time (Bellman 1954). Thus, FARMDYN delivers discounted farm household income at given netput prices and endowments. The corresponding average quantities of outputs sold, inputs bought, investment made and off-farm work supplied reflect yearly average activities of the optimal production plan over the planning horizon.

As marginal values of a MIP are conditioned on the current integer solution and do not consider that integers might change if a (quasi-) fixed factor increases, they might not reflect the actual shadow prices. That is why we derive the marginal returns to arable land and grassland from solving the model with increased endowments of arable land and grassland by one hectare and report the change in discounted income. Therefore, the marginal values of arable land and grassland consider how farming activities would change in the next ten years if an additional hectare of arable land or grassland could be used for agricultural production for ten years (the usual duration time of rental contracts in German agriculture is between eight and twelve years, Albersmeier *et al.* 2010), also including possible investments in a new stable if additional land becomes available.

In Step 3, we obtain optimal netput quantities, income and corresponding marginal returns to (quasi-) fixed factors for each farm of the farming population.

3.3 Determination of the meta-model (Step 4)

As a meta-model, we estimate a dual value function from the solutions of the MP model provided by step 3. Since the meta-model comprises the information about the technology of farms, a meta-model has to be estimated for each farm type by specialization separately. The possibility of farmers to switch from one agricultural production to another could be implemented by generating and estimating a sample of mixed farms that use various technologies.

3.3.1 Choosing the variables to be included in the meta-model

The inputs and outputs that are used as explanatory variables determine the farm household's costs and revenues from agricultural production and off-farm work. The endowments with (quasi-) fixed factors and prices of netputs are used as independent variables to explain the dependent variables discounted income, netput quantities as well as marginal returns to land. In opposite to estimating from real-world data, we control the data generation process by solving the MP model which allows us to also generate observations on marginal values.

As an example, Table 1 presents the lists of netputs simulated for dairy farms. The inputs include feed concentrates bought, variable costs of crops that are produced for feeding (such as maize silage, incl. fertilizer, plant protection products, electricity etc.), as well as investments made. Outputs are the amount of milk produced (other revenues such as from slaughtered cows or solved calves are reflected in the milk price), hours worked off-farm and exported manure. In regions with high livestock density, a farmer who exports manure makes a payment to an importing farmer. Therefore, exporting manure means a cost and is considered as a negatively valued output in the estimation of the value function (Kuhn *et al.* 2019; Schäfer and Britz 2017). The (quasi-) fixed factors characterize a farm household as an agent depicted in the ABM. For a dairy farm, we consider the number of hectares of arable land and grassland, the amount of labor available, and the construction year of the existing stable, as well as the milk yield per cow as an indicator of productivity. As described above, the farm endowment with land and labor is derived from the initial number of cows since this is the key attribute in the DOE for the farm branch dairy. We define a range of 40 to 150 milk cows per farm.

The construction year of the stable is included as (quasi-) fixed factor because a stable can only be used for 30 years. Once the stable reaches an age of 30, the farmer has to invest in a new stable in order to continue milk production. If the stable reaches the maximum age of 30 years in the optimization horizon of ten years, the farmer decides to reinvest in a stable or to quit milk production. This way, we can consider the age of a stable in the ABM and also include the possibility of farm exit due to a necessary large investment in a new stable. This is achieved by increasing the age of the stable with each time step of the ABM until a maximum age of 30 years and if a farmer invests in a new stable at a certain time step of the ABM, setting the age of the stable back to zero. Whether an agent has recently invested or will have to invest in a new stable within the next ten years is reflected in its discounted income. This way, it is possible to also include sunk costs related to a recent investment in a new stable and path dependencies which play a crucial role in agricultural production decisions (Huber *et al.* 2018). As the discounted income can be used to derive bids for land plots, the age of the current stable will have an influence on the willingness to pay for an additional plot of land.

Table 1. Variables included in the meta-model for the farm branch dairy.

Variable	Description	Factor range		
		Min	Max	Unit
Outputs		Netput price ranges		
Milk produced	Amount of milk produced [t]	310.00	360.00	€/t
Off-farm labor	Hours that a farmer works off-farm [h]	8.00	15.00	€/h
Manure exported	Amount of manure exported from the farm [m³]	1.00	20.00	€/m³
Inputs				
Feed concentrates	Sum of feed concentrates bought [kg]	0.80	1.20	€/kg
Crops	Sum of crops produced for feeding [kg]	0.80	1.20	€/kg
Investments	Sum of investments [1]	0.80	1.20	€
(Quasi-) fixed factors		Factor level ranges		
Arable land	Number of hectares of arable land	0.38	0.42	ha/cows
Grassland	Number of hectares of grassland	0.31	0.35	ha/cows
Milk yield	Milk yield per cow in 100 kg	80.00	86.00	*100 kg/cow
Labor units (lu)	Amount of farm labor available	28.00	38.00	cows/lu
Stable year	Construction year of the existing stable	1985	2010	

Note: Prices of feed, crops and investments are based on price indices composed of mean prices. Produced crops are solely fed to the animals and not sold on the market. Therefore, the crop price reflects the costs of crop production. Please also note that the export of manure means costs to the exporting farm. In the estimation of the value function, its price will, therefore, have a negative sign.

3.3.2 Definition of functional form

To approximate the behavior of the highly detailed MP model as good as possible, flexibility of the functional form of the value function is important. It must depict a multiple input, multiple output production function. Its derivatives will define input demand and output supply functions as well as marginal returns to limiting factors (Lopez 1982).

Inter alia, Diewert (1971, 1974), Christensen *et al.* (1973), Lau (1976) and Sidhu and Baanante (1981) propose flexible functional forms applicable to duality theory. To our knowledge, the choice of functional forms is quite limited if multiple inputs and multiple outputs are to be considered and convexity can be imposed to guarantee regularity, which is important for latter simulations. Based on the work of Diewert and Wales (1987, 1988) and Diewert and Ostensoe (1988), Kohli (1993) developed the symmetric normalized quadratic (SNQ) profit function (in our case value function as the MP delivers discounted income) that allows imposing global convexity, stays flexible and treats all inputs and outputs identically:

$$\pi\left(p,z\right)=\sum_{i=1}^{n}\alpha_i\,p_i+\frac{1}{2}\omega^{-1}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}p_ip_j+\sum_{i=1}^{n}\sum_{j=1}^{m}\delta_{ij}p_iz_j+\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{m}\gamma_{ijk}p_iz_jz_k \tag{I}$$

where π is the profit (in our case discounted income), $\alpha_i,\beta_{ij},\delta_{ij},\gamma_{ij}$ are the parameters to be estimated, p_i are the input and output prices, z_i are the (quasi-) fixed factors, $\omega=\sum_{i=1}^{n}\theta_i p_i$ is the price index for normalizing the prices and θ_i is the weights of prices for normalization (Henningsen 2014).

The estimation equations encompass the output supply and input demand equations x_i, derived by taking partial derivatives of the value function with respect to price p_i, and marginal returns m_j derived as partial derivatives towards the factor quantities z_j, according to the envelope theorem (Henningsen 2014; McKay *et al.* 1983).

$$x_i=\frac{\partial\pi(p,z)}{\partial p_i}=\alpha_i+\omega^{-1}\sum_{j=1}^{n}\beta_{ij}p_j-\frac{1}{2}\theta_i\omega^{-2}\sum_{j=1}^{n}\sum_{k=1}^{n}\beta_{jk}p_jp_k+\sum_{j=1}^{m}\delta_{ij}z_j+\frac{1}{2}\sum_{j=1}^{m}\sum_{k=1}^{m}\gamma_{ijk}z_jz_k \tag{II}$$

$$m_j=\frac{\partial\pi(p,z)}{\partial z_j}=\sum_{i=1}^{n}\delta_{ij}p_i+\sum_{i=1}^{n}\sum_{k=1}^{m}\gamma_{ijk}p_iz_k \tag{III}$$

As shown by the shadow price equation (equation III), marginal returns to fixed factors are determined by price effects and price-fixed factor effects. Accordingly, marginal returns to land vary not only due to different netput prices that the agents face but also due to joint effects of netput prices and endowments of farms with land, working units and other (quasi-) fixed factors. Therefore, the value function meta-modeling approach allows maintaining heterogeneity among farms of the same specialization with different farming structures and/or facing different prices. Only farmers with a similar farming structure and prices are assumed to derive the same optimal netput quantities and marginal returns to (quasi-) fixed factors. This observation points out that the value function is a dual representation of the technology. The value function does not fully depict the behavior of the agents in the ABM. Additional factors determining agents' decision making such as irrational or social behavior can be explicitly modeled in the ABM resulting in further heterogeneity among agents.

3.3.3 Estimation of the value function

Since we are particularly interested in the derivation of the marginal values to land, resp. the shadow prices of land, we estimate the netput equations (equation II) and shadow price equations (equation III) simultaneously, to inform the estimator on the marginal returns to land (McKay *et al.* 1983) that are also provided by FARMDYN. To our knowledge, that is a rather novel approach which reflects that other data sources such as farm samples used to estimate dual value functions are not providing observations on marginal values.

Corner solutions, resulting from in- or output quantities simulated as zero, frequently occur in our generated dataset and represent a particular challenge for the meta-modeling approach. For example, a farm may not supply off-farm labor as the returns to labor in the farm exceed the reserve wage; or the reserve wage becomes so high that the farm does not produce agricultural output and family members only work off-farm. If no off-farm labor is supplied, we can conclude that the internal return to labor is at or above the reserve wage, but we cannot assume that it is exactly at the reserve wage as required for a consistent estimation of the value function with a standard estimator. In real-world observed samples in which the data generation process is not controlled, such zero observations are potentially subject to self-selection bias such that two-stage procedures like limited information maximum likelihood (LIML) drawing on Heckman (1979) may become necessary. In our case, we can exclude all observations with any zero input or output from the estimation since we know that the underlying technology is identical for all farms by definition as defined by the structure and parameterization of the MP model. Still, corner solutions remain in the solution space of the MP model because of its integer variables. This is a particular challenge for the meta-modeling approach and discussed in chapter 4.

The SNQ value function is estimated as a seemingly unrelated regression (SUR) using the R package micEconSNQP (Henningsen 2014). Convexity on prices, which is an assumption of duality theory (Diewert 1973; Lau 1976; Lau 1986; Thijssen 1992), is imposed post-estimation where necessary based on Koebel *et al.* (2003). We slightly modified the R code to include equations for marginal returns to land.

At step 4, we obtain the estimates of the dual value function which represent the optimal production decisions of farmers originally simulated in the MP model. The estimated dual value function is now the meta-model of the MP model and can be integrated in the ABM.

3.4 Description of the ABM

ABMSim, the ABM we use for our modeling approach, was constructed to analyze structural change in farming in a spatial explicit setting. The landscape is generated using

CORINE (coordination of information on the environment) land cover data (European Topic Centre on Terrestrial Environment 2000) and differentiates between arable land, grassland, forest, housing, other urban fabrics, water bodies and other land types. The farming population is disaggregated in groups by specialization such as dairy, arable, pig fattening or mixed farming types. For each county in NRW, based on data from IT.NRW (2019), it generates the observed number of farms by specialization and size class (<5 ha, 5-10 ha, 20-50 ha, 50-100 ha, 100-200 ha, >200 ha). Initialization takes place by distributing the generated farms on available spots in the landscape, making sure that the farming structure at commune and county level is reflected (Schäfer *et al.* 2019). Once the farmsteads are allocated, the algorithm generates the agricultural plots with a random plot size from 1 pixel (= 1 ha) up to a chosen maximal plot size (Britz 2013a).

ABMSim consists of five modules in which the estimated coefficients of the meta-model are used to calculate incomes or marginal returns to (quasi-) fixed factors to depict decision making of agents in the ABM: land use change module, farm exit module, land market module, nutrient auction module (Schäfer *et al.* 2019) and milk delivery module. The modules of ABMSim are solved iteratively over distinct time steps of one year. In each year, economic drivers like exogenous prices or policies can be updated (Britz 2013a).

All markets included in ABMSim are represented as auctions and depict the interaction space of agents where they compete for e.g. land, manure disposal or milk delivery contracts. The discounted household income derived from the MP, resp. from the dual value function, can be used in the ABM to represent economic optimal production and investment decisions. In order to mimic real-world behavior of agents, a variety of behavioral rules can be applied. Bounded rational behavior of agents is included by e.g. the possibility to derive bids from observations in the agent's neighborhood or from an agent's average discounted income per ha. These behavioral rules can be applied only for a part of the agents. As a consequence, the population can differ in a way that some agents behave according to full economic rationality while others take bounded rational decisions (Britz 2013a).

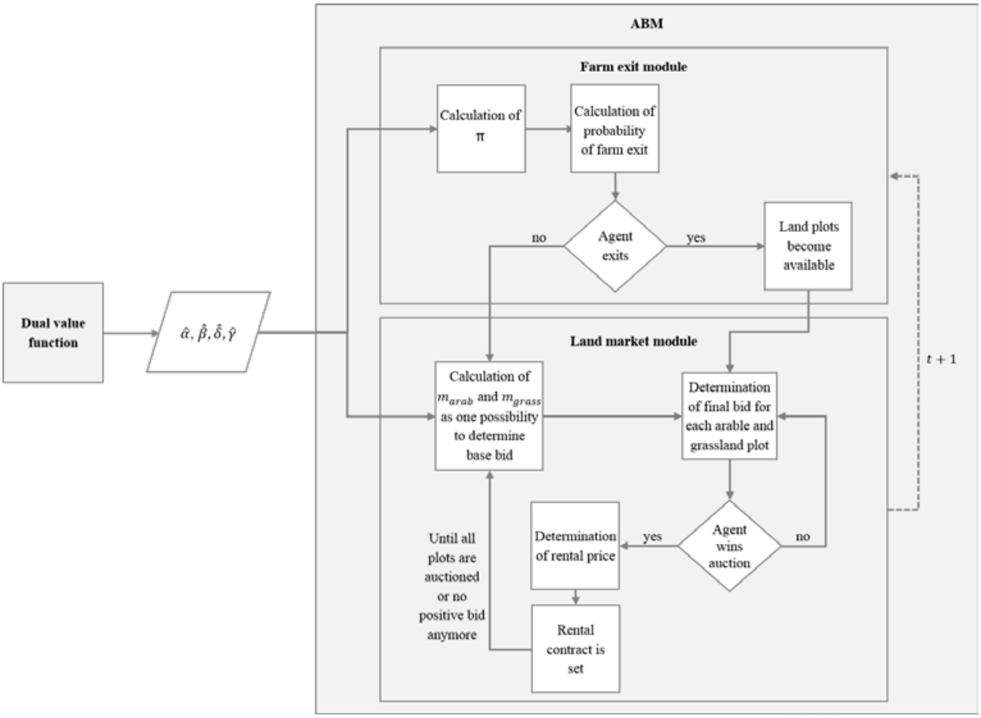
In the following, the farm exit and the land market modules of ABMSim will be briefly described in order to present the integration of the SNQ value function estimation in the ABM. These two modules are of particular importance for the simulation of structural change since they depict actions and interactions of agents which result in exit decisions and farm growth – the typical indicators of structural change in agriculture. A full description of ABMSim can be found in its model documentation (see Britz 2013a).

3.4.1 Integration of the meta-model in farm exit and land market modules (Step 5)

The estimated coefficients of the SNQ value function are used for the identification of agents that exit agricultural production based on discounted income calculations, and for the derivation of the bids of the agents based on the marginal returns to arable land and grassland. Figure 4 presents how the SNQ value function estimates are used in the two modules.

In the farm exit module, the probability of a farm exit in each period depends inter alia on each agent's current discounted income from farming (net of off-farm income). Combined with other information such as the agent's age and the probability to be employed outside agriculture, the calculated discounted income from farming (using

Figure 4. Connection of dual value function and ABM.



Note: Besides determining the base bid by calculating marginal returns to arable land (m_{arab}) and grassland (m_{grass}), it can also be defined based on average returns to land or average rents in neighborhood.

equation I) drives the probability of a farm exit[5]. If an agent exits, its current renting contracts end and the land owned (with the exemption of the farmstead) will be rented out. These plots are handed over to the land market module. Agents that do not exit agricultural production become potential bidders on plots in the land market.

The land market in ABMSim is a pure rental market and represented by a spatially explicit auction mechanism[6]. Agents who want to rent an additional plot of land put bids on the plots they are interested in. Free plots are plots where the rental contract ended or where the recent user exited the market. The agricultural plots are heterogeneous in location, size and type (arable land, grassland). The bidding behavior of agents is based on a base bid. One way to define it, is to use the marginal returns to land calculated from current prices, farm endowment and the estimated coefficients of the SNQ value function, as

[5] The derivation of the probability of farm exit can be found in the appendix.
[6] The auction mechanism is modeled as generic as possible in order to be applied to other market implementations, such as a market for milk delivery contracts or for manure disposal rights. A more detailed description of the auction algorithm can be found in the model documentation of ABMSim (Britz 2013a).

presented in formula III, and assuming full economic rationality. As the estimates of the value function are based on MP solutions of a ten year optimization, the calculated base bid includes information on the optimal production plan for the next ten years at current price expectations (in our case constant prices), also including potential large investments in the future, as presented in chapter 3.3.1. However, the base bide can also be defined according to the simulated discounted income per unit of land; or, as another possibility, an agent might use the average rent paid for rental contracts in the neighborhood. The last two options depict bounded rational behavior. The base bid is, first, reduced by transport costs to the plot depending on the distance to the farmstead and, second, increased by a markup for plots larger than one ha. The markup is used to reflect cost saving opportunities due to a large plot size. The resulting bid is restricted to not be larger than the base bid. As grassland and arable land are separate fixed inputs in the SNQ value function, agents place different bids on plots of arable land and grassland.

A rental contract of 10 years is set at a specific rental price between land owner and farmer winning the auction which depends on the chosen rules on auction order and price determination. After this land transaction, all bids for the remaining plots are recalculated for the winner of the auction because the willingness to pay for another plot of land has changed due to changed land endowment. The new marginal returns to land can easily be calculated by means of the SNQ shadow price equations (equation III) taking into account the increased land endowment. Due to the binding nature of rental contracts, bids may turn out to become unfortunate in the future because changes in prices or non-renewed rental contracts might change marginal returns to land and cause sub-optimal rental prices of current rental contracts.

4. Results

The dual value function is supposed to provide a good approximation for simulated netputs, discounted income and marginal returns to land to reduce the additional uncertainty introduced in the overall framework due to the replacement of the MP by a meta-model (Meckesheimer *et al.* 2002). Therefore, we focus on the fit of the meta-model in the result section, using a dataset of 1,002 dairy farms simulated by FARMDYN. These observations were kept from a sample of 5,000 farms after removing zero observations. We run the MP model as a dynamic programming model over the period from 2015 to 2025. Netput quantities refer to averages of 2015 to 2025. A descriptive summary of the simulated and estimated netput quantities, simulated incomes and marginal returns to land is presented in Table 2.

The values are discounted household incomes comprising not only returns from the farm operation, but also from working off-farm and from returns to accumulated cash. The model comprises optimal financing decisions based on different types of loans which differ in length and rates. The discount rate hence captures the time preference of a farmer and differs from the market based one. The farms simulated with FARMDYN are medium to large farms with a herd size between 40 and 150 cows and a land endowment of 32 to 110 ha in total, representing well the dairy farming structure in NRW (IT.NRW 2019).

Figure 5 presents scatterplots of the MP-simulated and fitted quantities from the SNQ value function of milk and off-farm labor supplied as outputs, and concentrates bought

Table 2. Key descriptives of simulated and estimated variables.

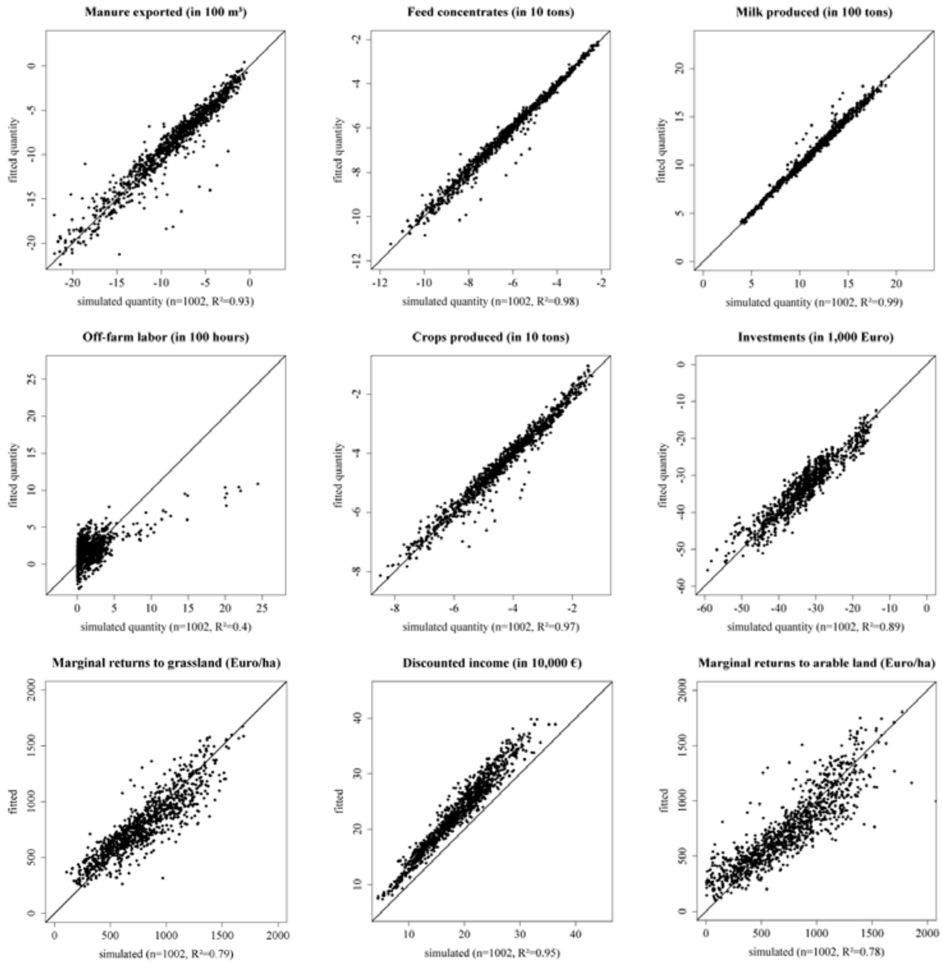
	Milk		Off-farm labor		Feed concentrates	
	MP-simulated	SNQ-fitted	MP-simulated	SNQ-fitted	MP-simulated	SNQ-fitted
Min	391.0	398.0	5.0	-299.6	-113,287.0	-96,854.0
Median	1,142.6	1,141,6	105.9	167.3	-62,849.0	-62,712.0
Max	1,922.3	1,913,3	2,442.0	793.5	-21,396.0	-19,769.0
R^2	0.99		0.35		0.95	
	Crops produced		Investments		Manure exported	
	MP-simulated	SNQ-fitted	MP-simulated	SNQ-fitted	MP-simulated	SNQ-fitted
Min	-84,903.0	-81,915.0	-59,192.0	-55,646.0	-2,593.3	-2,338.2
Median	-43,145.0	-42,838.0	-32,733.0	-32,996.0	-794.0	-785.7
Max	-13,354.0	-10,313.0	-13,587.0	-12,510.0	-40.6	40.0
R^2	0.97		0.89		0.93	
	Discounted income		Marginal returns to arable land		Marginal returns to grassland	
	MP-simulated	SNQ-fitted	MP-simulated	SNQ-fitted	MP-simulated	SNQ-fitted
Min	44,666.0	74,335.0	3.3	82.0	107.9	232.1
Median	189,989.0	233,354.0	716.8	673.6	771.6	754.2
Max	363,546.0	407,976.0	2,079.9	1,798.9	1,693.0	1,691.1
R^2	0.95		0.79		0.80	

Note: MP-simulated values represent the values that are provided by FARMDYN; SNQ-fitted values are values that are based on the estimation of the SNQ value function.

and crops produced for feeding, investments made and manure exported as inputs, as well as of the discounted incomes and marginal returns to land. The adjusted R^2 are very high (>93%) for the netputs milk, feed concentrates, crops and exported manure. The slightly lower R^2 for investments (89%) results from the assumption made in the MP that stables have to be bought in pre-determined sizes to reflect returns-to-scale. The integer character of variables make their estimation more difficult (see also discussion section in chapter 5). This can be especially seen in the moderate fit of the variable off-farm labor (40%). The dual value function with its continuous derivatives fails to fit the step-function that results from the integer character of the variable.

In opposite to that, the fit of average annual discounted income is with 95% very high, with a slight tendency to overestimate at high levels. The fit of the marginal returns to arable land and grassland is high (about 80%). The slightly lower fit compared to the estimated netput quantities is due to the complex interactions between the limiting production factors land and labor. The binary character of labor results in hard to predict changes in discounted incomes, if land endowment changes. These interactions are not fully captured by the shadow price equation derived from the SNQ value function.

Figure 5. Scatterplots of the dynamic dataset.



Note: Figures were created using R.

5. Discussion

To our knowledge, although a vast amount of literature can be found that investigates meta-modeling approaches for simulation models (e.g. Friedman and Pressman 1988; Jalal *et al.* 2013; Kleijnen 1979; Madu and Kuei 1994), inter alia simple Linear Programming (LP) models (e.g. Bailey *et al.* 1999; Johnson *et al.* 1996; Thangata *et al.* 2004), there is a lack of research that explicitly presents a meta-modeling approach of a complex MP model. Consequently, there is no evidence about the general performance of a linear meta-model of complex MIPs.

Our results suggest that a dual value function is able to provide, on average, a high fit for netput quantities and discounted income for the MP model FARMDYN analyzed in here. This might come as a surprise since MIPs provide corner solutions (due to the presence of integers) and are prone to overspecialization. The high fit found in here suggests that the large set of constraints of FARMDYN dampens that tendency and leads to a plausible and robust simulation behavior in the sense that changes in netput prices and factor endowments lead to a, on average, smooth response. This might imply that, if MP is used in an ABM to depict farming decisions, a certain degree of complexity is needed if a jumpy and hard to predict behavior has to be avoided. However, computing needs would be driven up – that is the starting point of using a meta-model instead.

Although replacing the integers by continuous variables would reduce computing time, a "normal" MP would eliminate returns-to-scale in investments and labor use which are now endogenously captured by the integers. We consider capturing returns-to-scale as important for the investigation of structural change. Note here that while the dual value function imposes convexity in netput prices, both convexity and concavity of income in fixed factors can be depicted.

As expected, the fit of the meta-model is lower if quantities are depicted by integer variables. Integers violate the assumed continuous relation between prices and netput quantities underlying the dual value function. However, this can also be considered as an advantage in some cases. The linear world of a MIP requires that investments come in pre-defined sizes if returns-to-scale are to be captured, whereas in reality, especially for building and structures, sizes can be rather flexibly chosen by the investing farmer. FARMDYN tries to overcome that problem partially by offering fine-grained stable sizes, but the basic problem remains. Compared to buildings and farming structure, for off-farm labor, the restrictive assumption is made in the MP that only 20 and 40 hour contracts are possible, besides a minimum wage job with only a few off-farm working hours a week. This explains the low fit of the netput off-farm work. In reality, however, family members might have some more flexibility to work part-time such that the smoothing effect of the meta-model might actually lead to a more realistic behavior. As such, the meta-model can also be understood as a way to interpolate over distinct points of the technology and the resulting solution space.

Furthermore, actions of agents in the presented ABM are derived from discounted income and marginal returns to (quasi-) fixed factors which are very accurately represented by the dual value function. Therefore, the more moderate fit for the variable off-farm labor should not invalidate the overall approach.

The main advantage of using a meta-model based on duality is that it provides a coherent framework to derive simultaneously netput quantities, (discounted) incomes and marginal returns. That is especially relevant if all these variables are needed in the ABM. If, for instance, only marginal returns to land are required, a simpler estimation approach not requiring a system estimation focusing on a high fit might be sufficient and more promising. Even if results for several variables are needed and a relatively high fit is obtained for all of them, the missing consistency might not be a concern. That would especially be true if the estimators are able to improve the fit for cases such as off-farm work where the dual approach cannot perform well by definition. Thus, approaches for instance from machine learning could be used instead of a theory consistent system estimation. As such, our results with the more restrictive dual approach define a kind of lower bound on the potential fit of a meta-model using more flexible fitting approaches.

Furthermore, in order to differentiate decision making of agents regarding planning horizons (e.g. milk delivery quantities in the current year as, to a certain extent, short-term decisions, medium-term decisions with regard to rental contracts, and long term decisions related to farm survival) more precisely, different value functions differentiated by planning horizons could be estimated and integrated in the model.. This way, differences in decision making of farmers could be depicted more precisely already at the estimation stage of the modeling approach. The modeling approach as a whole would yet become more complex, partly offsetting its advantages. As the paper showed, the dual value function is able to explain a complex MP model to a certain degree and is, therefore, suited to be implemented in an ABM to derive agent's decision making.

6. Conclusion

We present an approach to meta-model netput quantities, discounted farm-household incomes and respectively marginal returns to (quasi-) fixed factors from a highly detailed Mathematical Programming (MP) model with a dual symmetric normalized quadratic (SNQ) value function. The objective of the modeling approach is to set up a meta-model that represents the MP model in an agent-based model (ABM) to derive agent's decision making from it.

A set of parameters characterizes farm types by specialization, e.g. dairy farms, datasets are generated using MP for each and a dual SNQ value function is estimated. Based on duality theory, the estimation results shall be integrated in an ABM. This approach represents a less computing intensive and technically easier set-up of an ABM compared to the direct integration of a MP model into an ABM. This reflects that solving the MP model for each farm is computing time intensive and coding efforts to integrate the MP model into the ABM are higher compared to coding some few assignments necessary for the dual value function.

As presented in the paper, the estimation of a SNQ value function is able to fit the netput quantities, discounted incomes and marginal values of the MP model FARMDYN very well. Slightly lower fits can be explained by the integer character of some netputs which is more difficult to capture by the continuous character of the dual value function.

The value function meta-modeling approach maintains micro-economic consistency and derives mutually consistent simulation results at single farm-scale for discounted incomes, netputs and marginal returns to land. Even though the meta-model reflects micro-economic optimal behavior, the modeling approach still allows to introduce deviations from fully rational behavior. The reader shall be reminded that bidding behavior can be derived from both marginal and average costs which can be further modified in the ABM by behavioral rules. Furthermore, similar to MP, the dual value function provides a behavioral benchmark that can be compared to outcomes underlying alternative behavioral assumptions. By replacing the complex MP model, the dual value function relaxes computational restrictions while maintaining at the same time complex agent's behavior. It allows to easily depict large number of agents. Given that we obtained a high fit for most variables in our system estimation, more flexible approaches, e.g. from machine learning, might be interesting alternatives which could overcome inherent restrictions of a duality based approach such as continuous derivatives.

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Appendix
I. Calculation of probability of farm exit

The probability of farm exit is calculated from two elements:

1. The square root of the relation between the farmer's current yearly profit π_f and the maximum of (1) a pre-determined quantile of the profits in the farming population $\pi_{pop}^{quantile}$, and (2) the expected yearly net wage in the industrial sector minus commuting costs,
2. A normally distributed random number which accounts for not controlled determinants of exit decisions.

By settings parameters to zero, the effect of the different elements can be switched off.

Algebraically, the probability can be expressed as:

$$p_f = \sqrt{\pi_f / \left(\max\left(\pi_{exo}, \pi_{pop}^{quantile}\right)\right)} + N\left(\mu, \sigma^2\right)$$

If the stochastic variable p is below 0.5, the farm will exit. In this case, the agent's current renting contracts will end, while the land owned (with the exemption of the farm stead) will be rented out.

The expected yearly net wage of the farm in the industrial sector is determined from land cover data and the agent's age. First, the share of the industrial land cover *indShare* in a search radius around the farm stead is determined. This search radius is equal to the maximum commuting distance an agent is willing to accept. Thus, in rural regions with little urbanized cover characterized as non-residential, off-farm working opportunities are low. The probability to find work in the industrial sector is determined by the square root of the share of industrial land cover, multiplied by a factor f_{ind} expressing the relation between industrial land cover and open positions, and corrected for a term f_{age} that depends on the agent's age. The expected wage is then determined as the product of the wage in the industrial sector *wage* and the probability shown in the bracket:

$$E\left[wage\right] = wage * \left(f_{ind}\sqrt{indShare} - f_{age}\left[age_{cur} - age_{min}\right]\right)$$

Expected commuting costs *CommCost* are defined from the share of industrial land cover *indShare* times the maximal commuting distance *maxCommDistance,* and the commuting costs per km *commCostPerKm*:

$$E\left[commCost\right] = indShare * maxCommDistance * commCostPerKm$$

The exogenous alternative profit π_{exo} from working off-farm is finally defined as:

$$\pi_{exo} = E\left[wage\right] - E\left[commCost\right]$$

(Britz 2013a).

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