

# Challenges of the Farmland Market: Essays on the Tension between Financialization and Regulation

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## Abstract

In the recent decades, the German farmland market has faced enormous price increases. Those price increases caused intensive research. Among others, three streams of thought were especially in focus: farmland price determinants, the activities of nonagricultural investors and farmland market regulation. This thesis aims to contribute to those research streams within four cumulative research studies. The first study addresses the research stream concerning price determinants and revisits the price determinant soil quality within a panel cointegration regression approach. It addresses the research aims (1) to estimate the relative farmland price difference caused by soil quality over time and (2) to determine whether this relative price difference describes a long-run relationship over time. Therefore, aggregated farmland price time series within Germany from 1991 to 2020 have been used. The results of the study suggest that soil quality causes a significant relative farmland price difference over time. Furthermore, the aggregated time series within soil quality intervals follow a significant long-run relationship which indicates that the relative price share determined by soil quality is stable over time. The second contribution within this thesis addresses price determinants as well. Within a replication study of Ritter et al. (2020; Land Use Policy, DOI: [j.landusepol.2020.104771](https://doi.org/10.1016/j.landusepol.2020.104771)), the price determinant parcel size has been analyzed with two research aims: (3) to extend the geographical scope, which allows insights into regional differences in the price structure for farmland and (4) to evaluate the role of assumptions regarding the functional form for the size-price relationship. Recent research concerning the effect of parcel sizes on farmland prices showed ambiguous results. Therefore, the study of Ritter et al. (2020) had investigated the nonlinear form of the farmland size-price relationship for the German federal state Saxony-Anhalt with a non-parametric and a parametric approach. Within the replication study included in this thesis, the approach of Ritter et al. (2020) has been verified for Saxony-Anhalt and extended for the two German federal states Brandenburg and Lower Saxony. The results of the replication confirm the nonlinear form of the farmland size-price relationship. They also show that the functional form of this relationship differs between the three federal states and therefore probably across larger geographical regions in general. Furthermore, the form for grassland suggests different implications. Within the third study, the research stream nonagricultural investors is addressed more in detail. The engagement of nonagricultural investors is of rising

interest during the last decades, however, their motives to buy farmland are barely investigated. To address the question, a discrete choice experiment has been conducted in 2021 with 639 participants across Germany. The research goal of the study is an (5) investigation, whether the four groups of factors key investment information, subjective knowledge of finance, the attitude towards money and sociodemographic characteristics are potential predictors for choosing farmland as an investment. A mixed-logit approach revealed, that variables from all groups of factors had a significant effect on the decision to invest in farmland. The fourth study included in this paper contributes to the research stream “farmland market regulation”. Due to the specific attributes of farmland, the design and evaluation of farmland market regulation is challenging. A further issue is the age of several laws, which makes a comparison of the situation before with the actual situation complicated. Therefore, the fourth study addresses the research aim (6) to present an analytical framework, which allows for a holistic and structured evaluation of farmland market regulation instruments. The German farmland transaction law has been used an example to build the analytical framework out of four components: a careful evaluation of the process behind the regulation instrument, an identification of the concerned parties, a listing of their respective arguments concerning the law and weightings of those arguments. As a result, the analytical framework presents concerned parties, their arguments and exemplary weightings of those arguments in a clear form. The cumulative thesis gives valuable insights about recent price developments of the farmland market. Furthermore, it addresses research streams which had been followed up continuously over the recent decades with novel datasets and innovative methodical approaches.

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# **I Introduction**

Farmland markets are facing multiple challenges, which keeps them in focus of researchers, politicians, and the public. This attention has its origin in the essential meaning of land as an agricultural production factor. During the last decade, the farmland market was shaken by considerable price increases (Bahrs 2014; Hüttel et al. 2015; Plogmann et al. 2020; Tietz & Forstner 2014). Those price surges caused intensive research activities. General price determinants of farmland were intensively studied as well as potential reasons for unusual price developments and policy interventions. Specialized research activities within the field of agricultural economics made researchers aware to the fact that the farmland market is different from other markets, since the traded good is immobile and heterogenous. Its use and potential exclusivity are always of public interest. Furthermore, the farmland market is particularly of interest due to the fact that farmland is needed for food production and new challenges arise due to modern ownership structures. Governments continue to address the farmland market with regulations and institutions, caught in a field of tension between economic development, which drives an ongoing financialization of the farmland market, and a desired secure food production, which is resilient to economic developments. Many actors who pursue different land use strategies are competing on this market. Farmland is important for farmers as a production factor, but also interesting for investors as a countercyclical investment with safe returns (Painter, 2010). Furthermore, the heterogenous and local nature of farmland make investigations of market structures especially complex and challenging.

One of the most active areas of farmland market research are potential price determinants. Within those price determinants, several factors are predominantly investigated. For example, soil quality is one of the most important determinants of farmland prices (Maddison 2000; Nickerson et al. 2012; Ritter et al. 2020; Seifert et al. 2021). This implies that the potential of soil for agricultural production is crucial for farmland prices. Furthermore, the size of sold parcels has been identified as an important price determinant (Downing & Gamble 1983; Huang et al. 2006; Ritter et al. 2020). Other price determinants include for example urban proximity (Cavailhès & Thomas 2013; Guiling et al. 2009; Lehn & Bahrs 2018; Ma & Swinton 2012; Zhang & Nickerson 2015), livestock density (Huang et al. 2006; Lehn & Bahrs 2018) and climate (Maddison 2000). Methodically, most price determinants are investigated within hedonic pricing frameworks. Hedonic price theory describes the price of a good as a sum of its

attributes. This approach is exceptionally useful for farmland due to its heterogeneity and immobility. The potential farmland price determinants investigated in recent studies are well-known in the context of historic agricultural economics research. Farmland markets and issues related to them were studied continuously over the 20<sup>th</sup> century<sup>1</sup>. An early study of price determinants for farmland was for example made by Haas (1922), who made one of the first econometric regression analyses with farmland prices<sup>2</sup> as the dependent variable and investigated the effect of for example soil productivity, distance to market, type of road or size of market town. An early study of comparative farmland values in Iowa by Wallace (1926) stated additional potential price determinants, for example the distance to roads and markets, soil type and condition, and average yields. Furthermore, Wallace encouraged the use of scientific methods to investigate land values. George (1941) described this study of Haas as pioneering work and presented based on the findings a correlation analysis of farmland values, where he considered for example farm income or rate of tenancy as further price determinants. The effect of acreage allotments on farmland prices, which were especially relevant in tobacco areas in the US at this time, were further investigated by Mason (1946). However, this early research regarding farmland markets described above, which is still being pursued today, was conducted and presented during a time with limited computing capacity. As economic theory developed and computational resources expanded, the investigation of farmland markets reached more advanced stages. For example, Behrmann and Collet (1970) investigated determinants of South African farmland prices with consideration of a temporal dimension and found that among other things product prices, interest rates, population pressure and urban development had an effect on farmland prices over time. From the 1980s on, farmland market research reached higher intensity and the determination of farmland prices based on different potential determinants was increasingly described within theoretical hedonic price frameworks. One example was presented by Miranowski and Hammes (1984), who investigated the effect of soil quality as a heterogenous attribute on farmland prices. Another example was presented by Shonkwiler and Reynolds (1986) who discussed hedonic modeling approaches to investigate

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<sup>1</sup> To define a time frame for the literature review of this study, only publications from the 20<sup>th</sup> and the 21<sup>st</sup> centuries have been considered. Earlier studies might exist but are of lower relevance for the interest of this work and not accessible.

<sup>2</sup> While some studies investigate mainly farmland prices, others concentrate upon farmland values. Both terms have related meanings, although it is not necessarily the same. A price is determined within a transaction and considered as a market signal, while a value can also be an intrinsic, virtual idea which is not necessarily visible in the market. However, the literature review considers both terms. Therefore, “prices” and “values” are considered equally, but within the ongoing analysis, farmland prices will be determined as the variable of interest.



locational effects in the urban fringe and presented an empirical estimation for farmland prices in Florida. Downing and Gamble (1983) investigated farmland prices in Pennsylvania and found strong effects of the distance to metropolitan centers and the land type<sup>3</sup>. The approach of hedonic models for farmland prices has been followed up in recent research.

Farmland price determinants have been continuously present in agricultural economics research, and have shown their importance for farmland price investigation. However, the enormous price surges during the last decades caused new challenges for farmland market research. Reasons for those price surges could not solely be found in “conventional” price determinants such as soil quality, parcel size, and land type (e.g., grassland or arable land, for example). Therefore, other potential influences were explored. A dominant idea for the potential reason for the price increases is related to activities of nonagricultural investors<sup>4</sup> who buy farmland. The influence of those nonagricultural investors on farmland market developments have been an emerging focus area, particularly during the 2010s. For example, Forstner et al. (2011) presented a report, where the presence and the influence of nonagricultural investors was investigated with qualitative methods within different German study regions. The authors found that nonagricultural investors are a considerable share of agricultural stakeholders, but their influence varies between the regions studied. Forstner & Tietz (2013) built on this study and took a closer look on capital flows from non-regional companies on farmland markets, which are also a considerable component of agricultural land owners. Hüttel et al. (2015) investigated the question whether farmland markets must be protected from nonagricultural investors. Hüttel et al. (2015) investigated the potential presence of speculation bubbles on the farmland market and found no indices for such bubbles to exist. The investigation of nonagricultural influences on farmland market is not restricted to Germany. Magnan & Sunley (2017) found that there is an ongoing financialization of farmland in Saskatchewan, Canada, where investors use farmland investments to diversify their portfolios. Nickerson et al. (2012) investigated ownership trends in the U.S. and identified a nonagricultural owner share of 29% in 2007. For the Czech farmland market, Curtiss et al. (2021) proceeded a hedonic modelling approach and provided evidence for buyer type-specific

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<sup>3</sup> The term „land type“ is used here considering the original wording of Downing and Gamble (1983).

<sup>4</sup> The term “nonagricultural investor” can describe a broad range of potential stakeholders on the farmland market. It can include international companies, regional companies, private persons or funds. Within this literature review, those different types are not separated. When it comes to the definition of research question, a separation of those different groups is essential.

land valuations under increased farmland demand of investors. Within those literature examples, the considerable presence of nonagricultural stakeholders on the farmland market is undisputed. Meißner & Mußhoff (2022) gave evidence that for example in the German federal state Lower Saxony a considerable share of nonagricultural buyers was active on the farmland market for the entire observation period from 1984 onwards. The idea of nonagricultural investors who affect the market has also been investigated for several decades. For example, Murray (1944) discussed the advantages of a free farmland market and potential disturbances of it, caused by absentee investors or rapidly rising prices. The interest for farmland from the nonfarmers' perspective is reasonable. Farmland as an asset to diversify and secure portfolios is highly recommended within financial investment literature. Research has shown that farmland is valuable for diversifying portfolios with a countercyclical investment (Noland et al. 2011). Studies argue that farmland is an investment which is comparable to gold but offers better monetary returns than rents (Fairbairn 2014; Painter 2011). Therefore, a considerable share of nonagricultural investors on farmland markets is expectable and relevant for further investigations.

The concept of ownership of farmland by nonfarmers is disputed in research and society. There are fears that nonagricultural investors might endanger the agricultural structure and thus food production. In addition, an unhealthy distribution of land, which could also be driven by such nonagricultural stakeholders, is seen as a potential risk. Those issues are of course not only connected to nonagricultural investors; however, their engagement plays a role in the public discussion. The discussion of government control in farmland, which was already opened in earlier times by Murray (1944), is a continuous stream of thought in farmland market research. further elevated by ongoing farmland market regulation laws and institutions that are established in many countries. For example, the German land transaction law strives explicitly for the protection of the agricultural structure and a healthy ownership distribution of land (Netz 2018). Established institutions check every land purchase in Germany and decide whether the sale is approved or whether a local farmer receives a pre-purchase-right (Netz 2018). Poland has a similar legal framework for land transactions, which restricts land purchases by nonfarmers (Kurowska et al. 2020). Several other countries of the European Union, for example Belgium, France, the Czech Republic, and Italy, have installed pre-purchase rights for farmers, who get an advantage for acquiring land for food production (Ciaian et al. 2012). Sweden has installed Swedish county agricultural boards, which regulate the land market on a local level

(Lapping & Forster 1982; Öhlund et al. 2020). Several other countries have established even stronger farmland market regulation. In India, stabilization policies active since 1991 are explicitly addressing the freedom of agricultural workers from landlordism. Within this, a consequent redistribution of land from landlords to tenants was a focal point. Further, land ownership ceilings determine a maximum of land a family can own in some provinces and tenancy is illegal (Bakshi 2008; Hanstad et al. 2009). South Korea also had an extensive land reform to redistribute land from landlords to tenants and prohibits tenancy (Jeon & Kim 2000). Such farmland market regulation policies are subject to ongoing evaluation in research. For example, the model AgriPoliS is used to evaluate and simulate policy interventions in the farmland market (Heinrich et al. 2019). Ferguson et al. (2006) investigate the effect of restricted ownership on farmland values in Saskatchewan, Canada. Lehn & Bahrs (2018) identified that certain legal regulations reinforce a price-increasing effect and should thus be altered.

This thesis picks up the three described research streams within farmland market research and aims to contribute to literature in three ways: (i) it revisits selected price determinants on farmland markets with new methodological approaches and datasets, (ii) it contributes to a better understanding of nonagricultural buyers on the farmland market, and (iii) it presents a potential instrument to evaluate farmland policies considering modern agricultural stakeholder structures. To achieve those aims, this cumulative thesis contains four studies, which are continuing the research streams of farmland market research described above. The first study is revisiting the price determinant soil quality for farmland prices in a temporal dimension. It therefore contributes to a better understanding of the farmland price determinant soil quality with an application of cointegration regression analysis, a methodological approach which is new to the area of farmland market research to the knowledge of the authors. The second study is also contributing to the research stream which determines and investigates price determinants. It replicates the study of Ritter et al. (2020) and revisits the relationship of farmland prices and parcel size. For the analysis, two additional, rich datasets are used and the methodological approach is extended. The study contributes to a further use of non-parametric modelling approaches in farmland market research. The third study is addressing the research area of nonagricultural investors on the farmland market. Discrete choice methodology is used to study nonagricultural persons' investment decisions with farmland as an alternative. The fourth study within this cumulative thesis follows the research stream about farmland market

regulation. An analytical framework is developed which contributes to a better understanding of farmland market regulation perspectives.

In order to study the three overriding goals introduced in the previous section, several German federal states have been chosen as study area. Germany has several advantages as a study area due to its historical development, geographical attributes, and carefully created and complete administrative datasets. Two major historical attributes are affecting farmland markets and farmland market research: The political structure of federal states and the separation into Western and Eastern Germany from 1949 to 1990, which implied two different political systems with a different approach on farmland ownership and agricultural production for over 40 years. While a decentralized ownership and small-scaled agricultural production was promoted in Western Germany, the former east was aiming to centralize production and built large agricultural production units for cultivating state-owned land. Furthermore, Germany has a federal structure with several slightly different attributes for each federal state. Major differences lie not only in between the states of former Eastern Germany and former Western Germany, but also in between each of the federal states irrespective of their location between East and West.. For example, the states differ slightly in terms of their legal frameworks for the farmland market. Furthermore, Germany shows a high diversity of agricultural landscapes. While small farms and livestock dominate in the south, the north of Germany is characterized by arable land and a bigger farm size (Statistisches Bundesamt 2020). Also, in terms of soil quality and thus cultivated crops, the landscape is regionally diversified. An especially valuable attribute of the German farmland market are the rich databases, which exist on transaction level for several federal states and on aggregated levels for Germany as a whole.

The first contribution of this thesis is titled “Revisiting the relationship between farmland prices and soil quality” and is obtainable in section II. It contributes to the research stream of farmland market research which addresses price determinants. The article revisits soil quality as a farmland price determinant with a methodological approach which is new to the area of agricultural economics research. The described literature concerning price determinants of farmland gave evidence that soil quality is one of the most influential price determinants (Miranowski & Hammes 1984). Nearly every study concerning farmland prices is considering soil quality as an independent variable (Maddison 2000; Myrna et al. 2019; C. J. Nickerson & Zhang 2014; Ritter et al. 2020; Seifert et al. 2021; Yang et al. 2017; Zhang & Nickerson 2015). However, within those studies, potential changes of the effect of soil quality on prices over time

are rarely mentioned, since soil quality is mostly not in the center of the analyses. Hence, little is known about potential intertemporal changes of the effect of soil quality on farmland prices. Considering the farmland price surges in the 2000s and 2010s, intertemporal changes of the effect of soil quality could be considerable. Also the effects of climate change (Ortiz-Bobea 2020) and technological innovations in farming practices could affect changes over in the relationship between soil quality and farmland prices.

The article presented in section II of this thesis is therefore addressing the question of how the relationship of soil quality and farmland prices has developed over time. More precisely, the objectives of this article are defined as

- (1) to estimate the relative farmland price difference caused by soil quality over time  
and
- (2) to determine whether this relative price difference describes a long-run relationship over time.

To achieve those goals, a conceptual framework is set up, based on the hedonic price approach of Miranowski and Hammes (1984), where soil quality is a heterogenous attribute of farmland which determines the price. The data used for the empirical analysis is publicly available in the repository of the German statistical office (DeStatis 2021). It contains an aggregated farmland price time series from 1991 to 2020 for Germany. The price time series are available on a yearly basis, separated by parcel size intervals and soil quality intervals. Soil quality is measured with the German soil quality index (*Bodenpunkte*), which counts from 1 to 120 in steps of 1. It gives exact information about soil quality in Germany for each parcel, based on the German soil estimation law (*Bodenschätzungsgesetz*) and contains specific criteria for soil valuation (Herche 2019)<sup>5</sup>. The empirical analysis of the relationship between soil quality and the aggregated farmland price time series is two-fold. First, a naïve estimation is made to obtain the relative price difference between the average farmland price within each soil quality interval and the overall average farmland price. Second, cointegration regression analysis is used for a more elaborate estimation of the relative price difference. Within the cointegration regression analysis, two estimators are applied: the Fully Modified Ordinary Least Squares Estimator and the Dynamic Ordinary Least Squares Estimator.

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<sup>5</sup> Criteria for soil valuation within the German soil quality index are soil type, condition level and origin. The condition level contains humus content and root-ability (Herche 2019).

The study presented in section II contributes to literature in the following ways. To the best knowledge of the authors, it is the first cointegration regression approach in farmland market research. Further, it contributes to a better understanding of the price determinant soil quality within a temporal dimension. The results are helpful for a more comprehensive understanding of the price determinant soil quality, which is helpful for land valuation experts, farmland buyers and sellers, and policy makers.

The second article of this thesis, which is presented in section III is also addressing the farmland price determinants research stream. Besides soil quality, another important price determinant for farmland is parcel size. Although it is undisputed that parcel sizes have an effect on farmland prices, the results of the estimated effect of parcel size on farmland prices are ambiguous (Ritter et al. 2020). For example, Brorsen et al. (2015) identified a small parcel premium for parcels close to urban centers. Huang et al. (2006) investigated the relationship of farmland prices and parcel sizes in a linear model and found declining prices with increasing parcel size. However, Ritter et al. (2020) highlighted that results from different studies are varying and that the relationship between parcel size and farmland prices may take a nonlinear shape. To obtain a more accurate estimation of the relationship between farmland prices and parcel sizes, Ritter et al. (2020) combined a non-parametric Locally Weighted Least Squares Regression (LOESS) approach with a parametric regression model. They investigate whether the size-price relationship takes a non-linear form and includes positive as well as negative relations, depending on parcel size intervals. For their study, they used data by the Upper Expert Land Valuation Committee of the German federal state Saxony-Anhalt from 1994 to 2017.

The results of Ritter et al. (2020) gave evidence that a nonlinear relationship between parcel sizes and farmland prices is given and a small-parcel-premium exists. Nonetheless, their results were obtained based on one German federal state and leave open questions whether they are transferrable to other geographic regions. Therefore, the second article of this thesis replicates the study of Ritter et al. (2020) with two defined research goals:

- (3) to extend the geographical scope, which allows insights into regional differences in the price structure for farmland

and

- (4) to evaluate the role of assumptions regarding the functional form for the size-price relationship.

For addressing the first research goal, three additional datasets are included in this study. The farmland transaction data from the federal state Brandenburg, which covers the years from 1994 to 2021, and the farmland transaction data from the Federal state Lower Saxony, which covers the years from 1984 to 2015. Both datasets are provided by the Upper Expert Land Valuation Committees of the respective federal states. For Brandenburg, an additional dataset from the *Bodenverwertungs und -verwaltungs GmbH*<sup>6</sup> has been intersected. The data was also collected by the Upper Expert committee of Brandenburg, but it has been delivered separately for data protection reasons.

Methodically, the approach of Ritter et al. (2020) has been replicated. Following the definition of Christensen et al. (2019), the replication consist of four components: a verification, which repeated the previous analysis, a direct replication, which applied a modified approach on the original dataset, a reanalysis, where new datasets are analyzed with the original approach, and an extended replication, where new datasets were analyzed with the modified approach. Therefore, the study contributes to (i) a better understanding of the size-price relationship on farmland markets in different geographic regions, and (ii) to an extension and evaluation of methodological practices in farmland market research.

Besides the research stream which identifies and investigates farmland price determinants, the discussion about the engagement of nonagricultural investors on farmland markets gained higher relevance during the last decades. Farmland gained attraction as a financial investment (Fairbairn 2014; Noland et al. 2011; Painter 2010, 2011) which is connected to an ongoing financialization of the farmland market. The engagement of nonagricultural investors and their potential effect on farmland prices is increasingly discussed, especially in light of recent steep price increases (Curtiss et al. 2021; Hüttel et al. 2015; Magnan & Sunley 2017). However, little is known about the motivations and attributes of nonagricultural investors who are interested in buying farmland. Therefore, the third contribution of this thesis presented in section IV aims to contribute to a better understanding of farmland market investments of nonagricultural persons<sup>7</sup>. Investment research has shown that several individual factors are having an impact on investment decision. Studies have found that for example subjective knowledge of finance

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<sup>6</sup> The description of the datasets and the description of several institutions is given in detail within the respective article, presented in section III.

<sup>7</sup> Within this study, the heterogenous group of nonagricultural investors is reduced to private persons who buy farmland. This group is a considerable share of farmland owners.

has a considerable effect on investment decisions (Hadar et al. 2013), as well as the attitude toward money (Keller & Siegrist 2006a, 2006b) or socio-demographic characteristics (Barber et al. 2001). However, the literature concentrates mainly on stock market investments.

The objective for the third contribution of this thesis is to investigate whether such factors are also related to individual farmland market investments. Four groups of factors are selected for an investigation: key investment information, subjective knowledge of finance, the attitude towards money, and sociodemographic characteristics. The research goal can be formulated as an

- (5) investigation of whether the four groups of factors - key investment information, subjective knowledge of finance, the attitude towards money, and sociodemographic characteristics - are potential predictors for choosing farmland as an investment.

A discrete choice experiment was conducted for the purpose of this study. 639 participants answered 12 choice sets and a questionnaire. The survey was conducted online in 2021 in Germany with an external online panel provider. To be representative of the German population, four criteria were considered and set relative to the German population: Age groups, gender, federal state, and income. Germany is suitable as a study region due to its agricultural structure, where nonagricultural persons own a considerable share of farmland (Meißner & Mußhoff 2022). Further, a vivid rental market exists and the purchase of small land parcels that are affordable for private persons is possible. The study was set up as follows. First, the questionnaire was used to determine the subjective knowledge of finance, the attitude towards money, and the sociodemographic characteristics of each participant. For quantifying the subjective knowledge of finance and items which indicate the attitude towards money, Likert scales were used. Following that, the discrete choice experiment was conducted. It contains 12 choice sets with the investment alternatives financial product and farmland and a bank account as an opt out variant. The attributes contained key investment information. The study described in section IV contributes to existing literature in the following ways. First, it presents one of the first approaches of discrete choice experiments in farmland market research. Second, it is the first study to investigate intrinsic factors which might affect farmland investments of nonagricultural persons.

The engagement of nonagricultural investors leads to a considerable additional demand for farmland, which is beyond the demand of farmers. Public discussion fears this demand to be a



danger for food production, price stability of food and farmland, and sustainability of agriculture. Recent research has found that farmers have a negative attitude to nonagricultural farmland investments and are willing to accept farmland market regulation when they profit from it (Jauernig et al. 2023). Therefore, researchers are discussing and evaluating the need for and the design of farmland market regulation instruments.

The fourth study within this thesis is addressing the discussion and evaluation of farmland market regulation in section V. The study is motivated by the controversial discussion of farmland market regulation by researchers and the public. On the one hand, economists traditionally plead for market regulation to address market failures. Such failures on the farmland market are for example asymmetric information (Seifert et al. 2021), a lack of liquidity (Kionka et al. 2021), or land concentration (Plogmann et al. 2022). Therefore, the consideration of farmland market regulation is plausible. On the other hand, arguments for a free market exist as well. For example, the inadequate and untargeted design of farmland market regulation instruments is discussed (Busse 2019; Hoffmeister 2018). To contribute to this discussion, all parties and arguments involved concerning the farmland market and regulation instruments should be considered

The study presented in section V is addressing this issue within the research goal to

- (6) present an analytical framework, which allows for a holistic and structured evaluation of farmland market regulation instruments.

Therefore, the article follows three concepts described by Schelling (2010) and Straffin (1993). The first concept is the usage of numerical payoffs to describe the utility of an outcome. Therefore, the determination of individual utilities is possible. The second concept is the definition of certain actors, e.g., parties, which are affected by the respective regulation instrument and are potentially able to make decisions. The third concept is the usage of strategies, which lead to different utility payoffs for the different actors. As an example, for farmland market regulation, the German land transaction law is used to present the application of the analytical framework. The law is evaluated from the perspective of a politician oriented towards the public welfare. Within the analytical framework, arguments sorted by the respective actors are listed and payoffs are assigned.

The study contributes to the existing literature in the following ways: First, it delivers an analytical framework which is adapted to the requirements of the evaluation of farmland market

regulation. To the best knowledge of the authors, this is the first adaption of an analytical framework for farmland market regulation. Second, this framework contributes to a more structured and informative way to discuss farmland market regulation instruments. Policy makers, researchers, and agricultural stakeholders could profit from implementing such analytical frameworks to frame their argumentation.

The four studies introduced above are presented within the following sections II to V. They describe different aspects of the challenges of the farmland market in the tension field between financialization and regulation. In section VI, a conclusion of this thesis is presented. Within this, the studies and their respective results are summarized, as well as policy and methodological implications, which are of relevance for policy makers and further research.

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# I Revisiting the Relationship between Farmland Prices and Soil Quality

## **Authors**

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## **Abstract**

This paper aims to examine the relationship between soil quality and farmland prices over time. Soil quality is often used as an explanatory variable for farmland prices in hedonic price models. However, the agricultural land market has shown an enormous price increase over the last decade. Therefore, revisiting the relationship between soil quality and farmland prices over time is of high relevance. This study aims to analyze farmland price time series in Germany. The series are aggregated within soil quality intervals and within parcel size intervals, treated as panel units. The fully modified ordinary least squares (FMOLS) panel group mean and the dynamic ordinary least squares (DOLS) panel group mean estimators are applied within a cointegration regression approach to estimate the relation of the time series. We found that soil quality causes a relative farmland price difference within an identified long-run relationship.

## **Keywords**

Soil quality index, agricultural land market, farmland prices, FMOLS, DOLS

## **DOI**

<https://doi.org/10.1093/qopen/qoac017>

## II New Insights on Regional Differences of the Farmland Price

### Structure: An Extended Replication Study on the Parcel Size-Price Relationship

#### **Authors**

Henning Schaak, Luise Meissner, Oliver Musshoff

*Published in: Applied Economic Perspectives and Policy 45(3), 1427-1449*

#### **Abstract**

This study adds insights about the nonlinear effect of parcel sizes of farmland prices. Therefore, replications of Ritter et al. (2020, Land Use Policy, DOI: j.landusepol.2020.104771) is performed in four ways: A verification of the original results, a reanalysis of the original dataset with an alternative approach, a direct replication of the original analysis on two additional datasets for neighboring regions and an extended replication with the alternative approach on the additional datasets. The study contributes to literature within two dimensions: (i) the geographical scope, which allows insights into regional differences in the price structure for farmland and (ii) the role of assumptions regarding the functional form for the size-price relationship. The results of the extended replication show that the size-price relationship differs between geographically proximate federal states. Further, the results highlight the importance of assumptions imposed on functional forms of nonlinear relationships in hedonic regression studies.

#### **Keywords**

Agricultural land, farmland price, parcel size, replication study

#### **DOI**

<https://doi.org/10.1002/aepp.13366>

## III Financial Knowledge, Attitude towards money and Investment

### Decisions: New Insights for the Farmland Market

#### **Authors**

Luise Meissner, Michael Danne, Oliver Musshoff

*Forthcoming in: Applied Economics*

#### **Abstract**

A considerable share of farmland market activity is related to non-agricultural owners. Recent research has shown that those non-agricultural owners are likely to be private persons. However, little is known about potential factors which drive their decision to invest in farmland. This study aims to investigate four groups of factors which could affect the decision of non-agricultural persons to buy farmland: Key investment information, financial knowledge, the attitude towards money, and sociodemographic characteristics. Primary discrete choice data, which is representative for our study region Germany within four categories, has been collected for the purpose of this study. 637 participants were asked to invest in farmland, financial products or save their money in a bank account. A mixed logit approach revealed, that variables from each factor group are related to the decision to invest in farmland. According to the effect sizes, risk (volatility of returns), returns, a university degree and a preference for a secure investment performance are especially important factors for investment decisions. Furthermore, considerable differences exist between people with a high financial literacy score or a high level of self-assessed financial knowledge.

#### **Keywords**

Investment decisions, discrete choice modelling, farmland market, mixed logit model, individual attitudes

#### **DOI**

<https://doi.org/10.1080/00036846.2023.2293670>

## IV An Analytical Framework for Evaluating Farmland Market

### Regulation: Examining the German Land Transaction Law

#### **Authors**

Luise Meissner, Lisa Kappenberg, Oliver Musshoff

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#### **Abstract**

Farmland market regulation and related political interventions are prominent in the current discussion, in particular, because the market faces big price increases. This discussion is often shaped by subjective and emotional perceptions. Its complexity is increased by the considerable number of affected parties and opposing arguments. The parties involved may be focused on different aspects and have different requirements with regard to farmland market regulation instruments. The objective of this paper is to present an analytical framework for more efficient observation and evaluation of the ongoing discussion. The framework was developed using information about the relevant political interventions to structure the arguments and parties. It allows for a holistic evaluation of farmland market regulation. To provide an example of how farmland market regulation can be analyzed, the German land transaction law was broken down by process, parties, and arguments. Within the analytical framework, arguments are weighted individually. As a result, the various farmland market instruments can be discussed in a structured way. Additionally, the framework provides information about the utility of the respective instruments in defined cases from different perspectives.

#### **Keywords**

Analytical framework; German land transaction law; policy analysis; farmland market

#### **DOI**

<https://doi.org/10.3390/land1110175>

## VI Conclusion

The overriding research aims of this thesis were (i) to revisit price selected determinants on farmland markets with new methodological approaches and datasets, (ii) to contribute to a better understanding of nonagricultural buyers on the farmland market, and (iii) to present a potential instrument for evaluating farmland policies considering modern agricultural stakeholder structures. Therefore, four studies have been contributed which are presented in sections II to V. The results of those studies are summarized and discussed in the following. Also, methodological and policy implications are explained and future research challenges are presented.

The first study revisited the relationship between soil quality and farmland prices, and therefore contributes to the research stream which identifies and investigates farmland price determinants. The study addressed the research aim to estimate the relative farmland price difference caused by soil quality over time and to determine whether this relative price difference follows a long-run relationship over time. To answer those points, cointegration regression analysis was applied, which is to the best knowledge of the authors new to the area of farmland market research, to analyze farmland price time series that contain information about soil quality and parcel sizes in an aggregated form. The used dataset contained aggregated farmland price time series, which contain information about a certain soil quality interval and a certain parcel size interval. The time series were aggregated for Germany on an annual basis for the years 1991 to 2020. The first research goal of the study was to estimate the relative farmland price difference caused by soil quality over time. Therefore, a hedonic price model was set up where the price for farmland depends on soil quality. The relationship was estimated with three methodological approaches: a naïve estimation, a fully modified ordinary least squares estimation (Phillips and Hansen 1990) with the group mean approach by Pedroni (1996), and a dynamic ordinary least squares estimation (Kao and Chiang 2001). The results of those estimations delivered plausible, statistically significant parameter estimations for the relative price difference of farmland caused by soil quality. As expected, low quality levels lead to prices below the overall average, whereas high-quality levels lead to prices above the average. The second research goal of this study was to determine whether this relative price difference describes a long-run relationship over time. Within the cointegration regression, a long-run cointegration of the farmland price time series has been identified with the Pedroni test for panel cointegration (Pedroni 1999). Since the test assumes the existence of panel cointegration, a long-run relationship of the relative price differences caused by soil quality can be assumed.

The results of the study underline the importance of soil quality as a farmland price determinant also in a temporal dimension. They gave evidence that the relative price difference of farmland caused by soil quality describes a long-run relationship with the average farmland price over time. This result indicates

that farmland buyers and sellers do rely on soil quality as an important measure for determining the transaction price. The results of the study are limited by the dataset which is aggregated on a coarse level and contains only two price determinants as additional information. For further research, the use of more accurate data is useful to identify and investigate price determinants of farmland in more detail. However, with the usage of open data, the study contributes to the general aim of research to be transparent and publicly available. The classification of the article as open access and the availability of the dataset and the Stata code in open repositories contribute to this aim.

The second study which is included in this thesis is presented in section III. The study also addressed the research stream concerning price determinants and investigates the relationship between farmland prices and parcel size. Therefore, the study by Ritter et al. (2020), which revisited the relationship of farmland prices and parcel sizes with a parametric and a nonparametric modelling approach was replicated. The main research goals of the study were to extend the geographical scope of the original study, which allows insights into regional differences in the price structure for farmland, and to evaluate the role of assumptions regarding the functional form for the size-price relationship. For analyzing these goals, three unique datasets were used: the farmland transaction data from the respective Upper Expert Land Valuation Committees (Obere Gutachterausschüsse) of the respective federal states Brandenburg, Lower Saxony and Saxony-Anhalt in Germany. The replication was performed within four components: a verification, a direct replication, a reanalysis and an extended replication.<sup>1</sup> For analyzing the data of the three different federal states, a parametric estimation has been used as well as a nonparametric LOESS<sup>2</sup>-estimation. Regarding the first research goal, the results revealed considerable differences in the size-price relationship for farmland in the three federal states. Regarding the second research goal, a data-driven approach revealed a different functional form of the size-price relationship for different regions.

The results of the study presented in section III highlighted the regional variability of the size-price relationship for farmland prices. The nonlinear relationship between parcel size and price takes a different form for the three federal states Brandenburg, Lower Saxony and Saxony-Anhalt. Furthermore, the form of the size-price relationship for grassland in Brandenburg deviates from the conclusions made by Ritter et al. (2020). Last but not least, the data-driven approach in the study presented in section III defined a deviating model specification from the original study, which used a hypothesis-based approach to define the model specification. The study contributes to literature as follows. It gives further insights about the size-price relationship for farmland and identifies certain differences of this relationship in different geographic areas. Furthermore, the study highlights the difference between hypothesis-based

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<sup>1</sup> The types of replication are explained more in detail in the introduction section I as well as in the original study.

<sup>2</sup> The term LOESS refers to a

approaches and data-driven model selection procedures, which led to different functional forms for the size-price-relationships of the original study and the replication study.

The third paper in this thesis is presented in section IV and addresses the research stream concerning the effects of nonagricultural investors on the farmland market. The goal of the study was to perform an investigation into whether the four groups of factors key of investment information, subjective knowledge of finance, the attitude towards money, and sociodemographic characteristics are potential predictors for choosing farmland as an investment. To address this research aim, a discrete choice experiment was conducted, where key investment information was given as attributes. Additionally, a survey collected information about the subjective knowledge of finance, the attitude towards money, and sociodemographic characteristics of the participants. Within the obtained dataset, 639 participants answered 12 choice sets each. For analyzing the data, a mixed-logit approach has been applied which is based on the random utility theory (Manski 1977; McFadden 1975, 1986).

The results of the study presented in section IV showed that several variables within the four investigated groups of factors have a statistically significant effect on the investment decisions of the participants. For example, key investment information, such as the level of risk, expected returns, and the type of investment were statistically significant within the mixed logit estimation. Also, the subjective knowledge of finance has a statistically significant effect on investment decisions and led to increased investments in farmland compared to the alternative to leave the money on the bank<sup>3</sup>. The study contributes to the literature as follows. It presented the first investigation of intrinsic factors which might influence investment behavior in relation to farmland investments. Furthermore, the study gave evidence about the effect of individual attitudes and characteristics of the participants on investment decisions in general. Other implications are identified differences between financial product buyers and farmland buyers. For example, farmland buyers appeared to react more sensitively to risk than financial product buyers.

The fourth paper of this thesis presented in section V contributes to the research stream of investigating and evaluating farmland market regulation. The aim of this study was to present an analytical framework, which allows for a holistic and structured evaluation of farmland market regulation instruments. As an example for the framework, the German land transaction law was broken down by actors and arguments. To apply the framework for different defined scenarios, four steps are necessary. First, the process has to be described in detail. Second, the affected parties are listed. Third, respective arguments are identified and listed for each party. Fourth, the arguments are weighted under the different scenarios.

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<sup>3</sup> The results mentioned here are only exemplary. All results are described in detail within the study in section IV.



As a result, the framework shows the complex accumulation of parties and arguments in a structured form. The weightings of the arguments are flexible and enable different policy makers to make different weightings regarding to their attitudes. The results enable a better understanding of the complexity of farmland market regulation. Furthermore, parties, arguments, and weightings are obtainable in a clear form and different opinions about different arguments are clearly visible and comparable. For the example of the German farmland transaction law, the analytical framework delivers a linear curve which indicates the desired strength of regulation. Therefore, the analytical framework is a useful evaluation instrument and enables policy makers to evaluate farmland market regulation more efficiently.

The presented thesis aimed to contribute to the three farmland market research streams price determinants, nonagricultural investors, and farmland market regulation. The thesis used innovative methods and extensive datasets to answer research questions within the three areas. As a general point of discussion, it has to be said that all three research streams were investigated intensively in the past within farmland market research and will also be investigated intensively in the future. Continuously investigating the farmland market is important due to its special attributes such as the illiquidity and the heterogeneity of farmland.

The presented results enable policy makers to gain deeper and more detailed expert knowledge about the farmland market. The information about price determinants is relevant to enable a better understanding of market mechanisms for policy makers as well as for stakeholders and future stakeholders on the farmland market. This thesis explicitly contributes to a better understanding of the temporal development of the price determinant soil quality in section II. Policy makers should be aware of the fact that soil quality determines a certain share of the farmland price, regardless of intertemporal price changes. This means that the share determined by soil quality is instead a multiplier of a basis price, which is not undergoing intertemporal changes. Furthermore, the nonlinear relationship of the price determinant parcel size is investigated in detail within this thesis. The analysis which was carried out in section III for different geographic regions highlights the heterogeneity of farmland and underlines the need for regional policies and institutions which address the farmland market. Furthermore, this thesis enables policy makers to understand the motives and attitudes of potential nonagricultural farmland buyers more in detail.

Regarding the necessity for data in empirical research areas, this thesis also shows the general tradeoff in research between detailed secondary datasets, which are often not publicly available, and secondary open data, which is publicly available but often aggregated on coarse levels and thus less valuable for detailed investigations. Therefore, the results of this thesis are a good example of instances where open datasets are useful and where more detailed, restricted datasets are needed for. The open data used in section II was very valuable to revisit soil quality as a price determinant. Soil quality is often detected

as an important price determinant within restricted datasets, but calculation codes and respective datasets are often not available without additional effort. Therefore, the study also contributed to literature as a demonstration of the importance of soil quality as a price determinant within an analysis that is replicable by every reader with relatively small additional amount of effort. However, the limitations of the dataset are considerable. Therefore, the second presented study in section III showed the importance of the usage of restricted datasets, which are not publicly available for data protection reasons. Those datasets are usable for much more elaborated methodological approaches, which deliver detailed results. The increase of computational convenience in the handling of big datasets makes them also more useful for profound investigations. Therefore, a comprehensive understanding of a research area and transparent approaches for both researchers and the public needs both kinds of datasets. Furthermore, a third type of data used in research, namely primary, experimental data which was collected for the purpose of the study described in section IV, is presented within this thesis. This type of data is related to higher costs for questionnaire design and collection, but can offer detailed details about very specific research questions. It is therefore a valuable complement to the other datatypes.

All described research streams of farmland markets addressed in this thesis, namely the investigation of price determinants, nonagricultural investors, and farmland market regulation have in common that they have been investigated for several decades, and should continue to be investigated continuously in the future. Farmland markets tend to develop slowly due to their illiquidity. Therefore, research about them should be continued in agricultural economics. The contributions of this thesis are connected to multiple starting points for further research. The papers presented in section II and III were addressing the research stream of farmland price determinants. Although this area has been well-investigated over several decades, further research should proceed to determine and investigate farmland price determinants. An important foundation for this research might be the improved data availability, especially in the temporal dimension. The study presented in section II has shown that investigating farmland price determinants in a temporal dimension delivers further important insights about those issues. Due to improved data collection and storage in the digital age, as well as growing computational convenience, such investigations could be processed with elaborate databases and methodological approaches. Furthermore, effect sizes and types of price determinants for farmland might change in the future. For example, recent economic developments, urban sprawl (Zhang and Nickerson 2015), ecosystem services (Ma and Swinton 2012), or climate change (Ortiz-Bobea 2020) might affect farmland markets even more in the future. The second research stream addressed in this thesis is concerning the effect of nonagricultural investors. Such investors and other nonagricultural stakeholders will keep their importance as research subjects due to the ongoing financialization of the farmland market. Further research could discover the aims and interests of nonagricultural investors in more detail, and give further insights about their characteristics. The engagement of nonagricultural investors

is also interesting to study in more detail with regard to recent financial and macroeconomic crises. In particular, the financial crisis of 2007 might have had an effect on farmland prices, since the crisis affected the trust in the financial market among the population (van der Crujssen, de Haan, and Jansen 2016). Furthermore, within section IV of this thesis it has been shown that experimental approaches are a useful instrument to investigate several aspects of the activities of nonagricultural investors on farmland markets. Therefore, further approaches of experimental economics in farmland market research could be useful to investigate market actors. The fourth study presented in section V of this thesis addresses a third research stream, namely the investigation and evaluation of farmland market regulation instruments. Policies which address the farmland market are important to discuss since they might address potential market failures, such as asymmetric information (Seifert, Kahle, and Hüttel 2021) or illiquidity (Kionka et al. 2021). Such failures might develop in certain directions in the future, which could change the way those failures should be addressed. An example is the German land transaction law, which is investigated as an exemplary in section V. Due to the German land transaction law's age and its formation under a different agricultural structure which has since developed further, an ongoing evaluation of the law is important to ensure its efficiency and accuracy. Therefore, farmland market regulation should also be a central topic for further research. Methodically, applications of game theory and bio-economic modelling could be interesting for further evaluations of farmland market regulation.

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## Publication List

### Publications:

Meissner, L., Danne, M. & Musshoff, O. (2023). 'Financial knowledge, attitude towards money and investment decisions: new insights for the farmland market', forthcoming in *Applied Economics*, DOI: 10.1080/00036846.2023.2293670

Schaak, H., Meissner, L., & Musshoff, O. (2023). 'New insights on regional differences of the farmland price structure: An extended replication study on the parcel size–price relationship', *Applied Economic Perspectives and Policy*, ahead-of-print. DOI: <https://doi.org/10.1002/aep.13366>.

Meißner, L., Kappenberg, L., & Mußhoff, O. (2022). 'An Analytical Framework for Evaluating Farmland Market Regulation: Examining the German Land Transaction Law', *Land*, 11/10: 1-12. DOI: 10.3390/land11101759

Meißner, L., & Mußhoff, O. (2022). 'Revisiting the Relationship Between Farmland Prices and Soil Quality', *Q Open*, 2/2: 1-15. DOI: 10.1093/qopen/qaac017

Meißner, L. & Mußhoff, O. (2022). 'Transaktionen landwirtschaftlicher Nutzfläche in Niedersachsen: Die Bedeutung der nichtlandwirtschaftlichen Käufer im zeitlichen Verlauf', *Berichte über Landwirtschaft - Zeitschrift für Agrarpolitik und Landwirtschaft*, 100/1: 1-23. DOI: 10.12767/buel.v100i1.377

Sagemüller, F., Meißner, L. & Mußhoff, O. (2021). 'Where Can the Crow Make Friends? Sci-Hub's Activities in the Library of Development Studies and its Implications for the Field', *Development and Change*, 52/3: 670-83. DOI: 10.1111/dech.12638

### Conference Proceedings:

Meißner, L., Danne, M., & Mußhoff, O.: Subjective knowledge, attitude to money and investment decisions: New insights for the farmland market. Paper presented at the joint National Agricultural Credit Conference (NACC) and NC-1177 Meeting, October 17-18 2022, Federal Reserve Bank of Chicago, Detroit Branch Office, USA.

Meißner, L., von Hobe, C., & Mußhoff, O.: A small area approach to estimate and interpolate farmland values on community level. Paper presented at the EAAE PhD Workshop, June 22-24 2022, Università di Parma, Italy.

Meißner, L., & Mußhoff, O.: Does farmland market regulation generate utility? Discussing arguments and actors within the German land transaction law. Paper presented at the Annual Conference of the Agricultural Economics Society (AES), April 4-6 2022, KU Leuven, Belgium.

Meißner, L., & Mußhoff, O.: The intrinsic value of soil quality in farmland prices: Is the German soil quality index a stable indicator? Paper presented at the 61th Annual Meeting of the Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaus e.V. (online conference), September 23, 2021.

Meißner, L., Plogmann, J., & Mußhoff, O.: Are Policy Changes Visible in German Farmland Price Time Series? Paper presented at the International Conference of Agricultural Economists (ICAE) (online conference), August 17-21, 2021.

Meißner, L., Plogmann, J., & Mußhoff, O.: Are shocks in German farmland price time series random or reasoned by political events? Paper presented at the 60th Annual Meeting of the Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaus e.V. (online conference), September 23-25, 2020.

Meißner, L., Plogmann, J., & Mußhoff, O.: Are outliers in farmland price time series random or reasoned in political and economic events? Poster presented at the Agricultural & Applied Economics Association (AAEA) 2020 Virtual Meeting, August 10-11, 2020.

## **Declaration of Contributions**

I hereby declare my own contribution to each paper of this dissertation in detail.

### **Article: Revisiting the Relationship Between Farmland Prices and Soil Quality (Section II)**

Contributions: The article was written in cooperation with Oliver Mußhoff. The following working packages were taken by me: Idea and conceptualization with feedback by Oliver Mußhoff; data collection; calculations and interpretation of results in close cooperation with Oliver Musshoff, writing in cooperation with Oliver Mußhoff; two revisions of the paper in cooperation with Oliver Mußhoff.

### **Article: New Insights on Regional Differences of the Farmland Price Structure: An Extended Replication Study on the Parcel Size-Price Relationship (Section III)**

Contributions: The article was written in cooperation with Henning Schaak and Oliver Mußhoff. The following working packages were taken by me: data collection and cleaning in cooperation with Henning Schaak and Oliver Mußhoff, support of the calculations led by Henning Schaak, interpretation of the results in close cooperation with Henning Schaak and Oliver Mußhoff, writing in Collaboration with Henning Schaak and Oliver Mußhoff, two revisions of the paper in cooperation with Henning Schaak and Oliver Mußhoff.

### **Article: Financial Knowledge, Attitude towards Money and Investment Decisions: New Insights for the Farmland Market (Section IV)**

Contributions: The article was written in cooperation with Michael Danne and Oliver Mußhoff. The following working packages were taken by me: Idea and conceptualization in cooperation with Michael Danne and Oliver Mußhoff; data collection in cooperation with Michael Danne and Oliver Mußhoff; calculations in cooperation with Michael Danne; interpretation of results in cooperation with Michael Danne and Oliver Mußhoff, writing in cooperation with Michael Danne and Oliver Mußhoff, one revision of the paper in cooperation with Michael Danne and Oliver Mußhoff.

### **Article: An Analytical Framework for Evaluating Farmland Market Regulation: Examining the German Land Transaction Law (Section V)**

Contributions: The article was written in cooperation with Lisa Kappenberg and Oliver Mußhoff. The following working packages were taken by me: Idea and conceptualization in cooperation with Oliver Mußhoff; development of the analytical framework in cooperation with Oliver Mußhoff, analysis and interpretation of the results in cooperation with Lisa Kappenberg and Oliver Mußhoff, writing in cooperation with Lisa Kappenberg and Oliver Mußhoff.



## **Eidesstaatliche Erklärungen**

Hiermit erkläre ich eidesstaatlich, dass:

1. Diese Arbeit weder in gleicher noch in ähnlicher Form bereits anderen Prüfungsbehörden vorgelegen hat.
2. Ich mich an keiner anderen Hochschule um einen Doktorgrad beworben habe.

Göttingen, den 19. Juli 2023 \_\_\_\_\_

(Unterschrift)

Hiermit erkläre ich eidesstaatlich, dass diese Dissertation selbstständig und ohne unerlaubte Hilfe angefertigt wurde.

Göttingen, den 19. Juli 2023 \_\_\_\_\_

(Unterschrift)