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Risk management of German fruit farmers: a comparison of different approaches

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Zusammenfassung

Obwohl Obst und Gemüse auf lediglich 1,3% der landwirtschaftlichen Produktionsfläche angebaut wird, spielt der Gartenbau eine wichtige wirtschaftliche Rolle in Deutschland. In den vergangenen Jahren war dieser Sektor mit vielen Herausforderungen, wie z.B. Ertragsverlusten durch Wetterextreme oder geringen Erzeugerpreisen durch den russischen Importstopp, konfrontiert. Jedoch spielt der Gartenbau in der agrarökonomischen Risikomanagementliteratur nur eine untergeordnete Rolle. In der vorliegenden Dissertation wird am Beispiel von deutschen Obstbaubetrieben der Risikomanagementprozess von klein- und mittelständischen Gartenbaubetrieben ganzheitlich untersucht. Fragestellungen, wie die Bewertung unternehmensrelevanter Risiken, die Bewertung von Risikomanagementinstrumenten sowie die Ableitung für den Bedarf neuer Instrumente bzw. politischen Handlungsbedarf stellen dabei den Kern der Dissertation dar.

Die bestehende Risikomanagementliteratur in der agrarökonomischen Forschung weist eine Fülle an Methoden auf, um die unterschiedlichen Fragestellungen zu bearbeiten. Diese können im Wesentlichen quantitativer (Ansätze mit objektiven Wahrscheinlichkeiten), semi-quantitativer (Ansätzen mit subjektiven Wahrscheinlichkeiten) und qualitativer (z.B. Cognitive mapping; nicht im Fokus dieser Arbeit) Forschung zugeordnet werden. Überwiegend finden in der bestehenden Literatur quantitative Ansätze Anwendung, was jedoch in den vergangenen Jahren zunehmend Kritik hervorgerufen hat. Kritikpunkte sind dabei insbesondere die Anforderung an die Daten sowie die Datenverfügbarkeit, die notwendige Methodenkompetenz sowie die daraus resultierende limitierte Praxistauglichkeit oder die Konzentration auf Risiken, die messbar, aber womöglich nicht entscheidungsrelevant sind.

Um die Zielstellung dieser Arbeit zu bearbeiten, wurden die einzelnen Ansätze miteinander verglichen. Dabei wurden folgende Vergleichskriterien herausgearbeitet: Fragestellung (spezifisch bis holistisch), Betrachtungszeitraum, Anforderungen an die Daten, Verfügbarkeit der Daten, Zeit für die Datenerhebung, sowie Ursachen für mögliche Verzerrungen. Daraus abgeleitet wurden für die Teilfragestellungen der Dissertation die jeweils passenden Methoden identifiziert und die Ergebnisse aus der Verwendung quantitativer und semi-quantitativer Ansätze miteinander verglichen.

Im ersten Teil der Dissertation wurde am Beispiel von 105 deutschen Obstbaubetrieben der Risikomanagementprozess mittels einer Onlineumfrage erhoben und analysiert. Die Umfrage setzte sich aus drei Teilen zusammen: Die Ermittlung der Risikoeinstellung, die Analyse des Risikomanagementprozesses sowie die Erhebung von soziodemographischen Daten. Die Kernergebnisse der Studie lassen sich wie folgt zusammenfassen:

Beide Verfahren, die zur Messung der Risikoeinstellung eingesetzt wurden (Selbsteinschätzung, unternehmensbezogene Statements), weisen eine bipolare Verteilung auf, allerdings besteht nur eine sehr schwache Korrelation zwischen den Ergebnissen aus den beiden Messverfahren. Die schwache Korrelation bestätigt die situationsbedingte Abhängigkeit der Risikoeinstellung. Die bipolare Verteilung der Risikoeinstellung erfordert eine Anpassung vorhandener Modellansätze, um auch risikofreudige Entscheidungsträger berücksichtigen zu können. Wie zu erwarten war, sind Produktions- und Preisrisiko die wichtigsten Risikokategorien, gefolgt vom Personen-, Kosten-, Vermarktungs-, Anlagen- und Finanzrisiko. Innerhalb der Risikokategorien besteht ein hoher Konsens bei der Bewertung der Einzelursachen beim Produktionsrisiko, wohingegen das Preisrisiko stark betriebsabhängig ist. Die wichtigsten Ursachen für das Produktionsrisiko sind Hagel und Frost. Die Ergebnisse zeigen weiterhin eine starke Korrelation zwischen der Schadenserfahrung sowie der Risikobewertung, was auf eine mögliche subjektive Verzerrung hindeuten kann. Die wichtigste Risikomanagementstrategie stellt die Diversifizierung dar. Dabei spielt sowohl die Diversifizierung im Hinblick auf Kulturen, Vermarktungswege als auch im Hinblick auf zusätzliche Betriebszweige eine wichtige Rolle. Die Analyse zeigte weiterhin, dass ein hoher Zufriedenheitsgrad mit der Diversifizierung, insbesondere im Hinblick auf die Vermarktungswege besteht. Zwischen Hagelversicherung und Hagelnetz besteht hinsichtlich des Einsatzumfangs und der Zufriedenheit mit den eingesetzten Instrumenten eine große Diskrepanz. Bemerkenswert ist, dass 16% der befragten Betriebe sowohl Hagelnetz als auch Hagelversicherung einsetzen.
Das Personenrisiko wird stark unterschätzt, die Betrachtung der Einzelursachen macht jedoch die hohe Relevanz deutlich. Dabei unterscheiden die befragten Betriebsleiter zwischen dem Personenrisiko, das den Betriebsleiter und die Familienarbeitskräfte betrifft und dem Personenrisiko, das Mitarbeiter und Saisonarbeitskräfte betrifft. Um sich selbst und Familienarbeitskräfte abzusichern, werden hauptsächlich Versicherungen (Unfallversicherung, Lebensversicherung) eingesetzt. Innerbetriebliche Instrumente, wie die Dokumentation der Arbeitsabläufe oder die Ausstellung einer Generalvollmacht für den Notfall stellen wichtige Instrumente zum Risikomanagement dar, werden allerdings in der Praxis noch nicht flächendeckend eingesetzt. Um das Personenrisiko, das Mitarbeiter und Saisonarbeitskräfte betrifft, zu reduzieren, setzen die Betriebsleiter auf Mitarbeiterzufriedenheit sowie frühzeitige Absprachen. In zukünftigen Studien sollte dieser Risikokategorie mehr Beachtung geschenkt werden, insbesondere zu Themen, wie der frühzeitigen Regelung der Hofnachfolge, dem innerbetrieblicher Notfallplan oder den rechtlichen Vorgaben für die Beschäftigung von Saisonarbeitskräften aus Drittländern.
Mittels eines Expected Utility Ansatzes (quantitativer Ansatz) wurden im zweiten Teil der Dissertation verschiedene Optionen zur Reduzierung des Hagelrisikos untersucht. Die Basis für

die Studie stellte eine 10-jährige, obstanlagenspezifische Zeitreihe von Versicherungsdaten dar. Ziel der Studie war es, die Strategie mit dem höchsten Nutzen für Obstproduzenten zu identifizieren, in Abhängigkeit von dem örtlichen Hagelrisiko, dem Ertragspotenzial, der finanziellen Lage des Betriebs sowie der Risikoeinstellung. Insgesamt wurden 105 Obstanlagen untersucht. Diese können in vier Gruppen zusammengefasst werden. Unabhängig von der Risikoeinstellung, ist es in der ersten Gruppe (geringes Hagelrisiko, geringes Ertragspotential) am effizientesten, wenn kein Risikomanagementinstrument eingesetzt wird. In der zweiten Gruppe (hohes Hagelrisiko, geringes Ertragspotenzial) stellt die Hagelversicherung das effizienteste Instrument dar. Die Ergebnisse werden nicht von der Risikoeinstellung beeinflusst. Für die dritte Gruppe (geringes Hagelrisiko, hohes Ertragspotenzial) ist für risikoneutrale bis leicht risikoaverse Obstproduzenten das Hagelnetz die effizienteste Absicherung, mit steigender Risikoaversion ist jedoch die Hagelversicherung im Vorteil. Dies kann mit den Kosten für die Absicherung begründet werden: Im Falle des Hagelnetzes nehmen die Kosten pro Tonne Ertrag ab, sind jedoch im Hinblick auf das örtliche Hagelrisiko immer konstant. Bei der Versicherung steigen die Absicherungskosten mit steigendem örtlichen Hagelrisiko und mit steigendem Ertrag an. In Jahren mit niedrigen Erträgen jedoch kann die Versicherungssumme angepasst werden, wohingegen die Kosten für das Hagelnetz konstant bleiben. Diese Flexibilität ist ein wesentlicher Vorteil der Versicherung im Vergleich zum Hagelnetz. In der vierten Gruppe (hohes Hagelrisiko, hohes Ertragspotenzial) ist das Hagelnetz immer das effizienteste Instrument, unabhängig vom Vermögen und der Risikoeinstellung. Betrachtet man die Ergebnisse im Zusammenhang mit der Zufriedenheitsanalyse aus der ersten Studie kann man festhalten, dass die Hagelversicherung trotz häufigen Einsatzes nicht für jeden Betrieb das richtige Risikomanagementinstrument ist. Für die Entscheidung zwischen Hagelnetz und Hagelversicherung sollten zudem die Art der Vermarktung sowie die Sortenwahl berücksichtigt werden.

Im dritten Teil der Arbeit wurde das Preisrisiko sowie die Diversifizierung von Kulturen und Vermarktungswegen als Preisrisikomanagementstrategie untersucht. Mittels 9-jähriger Preiszeitreihen für verschiedene Obst- und Gemüsekulturen wurden die verschiedenen Vermarktungswege im Hinblick auf die Volatilität der Erzeugerpreise hin untersucht. Lediglich zwischen Apfel und Erdbeeren besteht ein signifikanter Unterschied in der Preisvolatilität. Die Vermarktung über den Großmarkt weist in allen Fällen eine deutlich geringere Erzeugerpreisvolatilität auf als die Vermarktung über die Erzeugerorganisation. Eine signifikante Zunahme der Erzeugerpreisvolatilität in den vergangenen 9 Jahren konnte nicht nachgewiesen werden; in Einzeljahren kam es jedoch dennoch vereinzelt zu Preisschocks, z.B. auf Grund von Wetterereignissen oder politischen Krisen. Durch die Diversifizierung von Vermarktungswegen kann das Preisrisiko reduziert werden, unter der Voraussetzung, dass ein Zugang zu mehreren Vermarktungswegen besteht. Auch die Ergebnisse aus der ersten Studie zeigen, dass die

befragten Obstbauern mit der Diversifizierung der Vermarktungswege sehr zufrieden sind. Da jedoch nicht jeder Produzent Zugang zu mehreren Vermarktungswegen hat, besteht dennoch der Bedarf nach neuen, innovativen Instrumenten zum Management des Preisrisikos.
In der vorliegenden Doktorarbeit wurden für die Bewertung des Preis- und Produktionsrisikos sowie einzelner Instrumente zum Management dieser Risiken quantitative und semi-quantitative Ansätze kombiniert. Die Ergebnisse zeigen, dass die Studien sich gegenseitig ergänzen. Insbesondere für klein- und mittelständische Unternehmen sollte deshalb ein integrierter Risikomanagementansatz etabliert werden. Die subjektive Bewertung von Risiken und Risikomanagementinstrumenten stellt ein probates Vorgehen dar, um mit fehlenden Daten oder Risiken, die nicht quantifizierbar sind, umzugehen. Die Kombination mit quantitativen Ansätzen schränkt das Risiko von Verzerrungen (beispielsweise durch Heuristiken) ein und kann somit dazu beitragen, das betriebliche Risikomanagement zu optimieren. Für Obstproduzenten sollte ein, wie im Rahmen dieser Dissertation entwickelter Risikomanagementprozess, in Form eines Modules in Farmmanagementsysteme integriert werden. Dabei ist es wichtig, das die Farmmanagementsysteme künftig alle relevanten Betriebsinformationen enthalten, von der Dokumentation des Pflanzenbaus bis hin zum Risikomanagementmodul.
Abschließend wurden die aktuellen Reformvorschläge für die Gemeinsame Agrarpolitik nach 2020 hinsichtlich ihrer Relevanz für den Gartenbau auf Basis der vorliegenden Ergebnisse analysiert. Die Vorschläge können in sechs Themengebiete aufgeteilt werden: Beibehaltung der finanziellen Unterstützung, Wissenstransfer, Stärkung der Erzeugerorganisationen, Ausbau bzw. Förderung der vorhandenen Risikomanagementinstrumente, Preistransparenz und Beschränkung der Marktmacht des Lebensmitteleinzelhandels. Insbesondere bei den Themenfeldern Beibehaltung der finanziellen Unterstützung sowie Stärkung der Erzeugerorganisationen herrscht Einigkeit zwischen den Vorschlägen der Europäischen Kommission sowie denen der Interessensverbände (Copa-Cogeca, Bayerischer Bauernverband), da diese beiden Bereiche für die Betriebe den größten Hebel darstellen.
Das Themenfeld Wissenstransfer ist ein zentraler Aspekt in dem Vorschlagspapier der Europäischen Kommission. Hierfür schlägt die Europäische Kommission eine Plattform vor, auf der Wissen zu bereits bestehenden Risikomanagementinstrumenten abgerufen werden kann sowie Erfahrungen zu diesen ausgetauscht werden können. Diese Plattform wird seitens der Europäischen Kommission auch als Chance verstanden, Informationen zum Bedarf zusätzlicher Instrumente zu erhalten. Die Plattform soll sich an Landwirte, Berater sowie Politiker richten. Wie die Ergebnisse der vorliegenden Dissertation zeigen, besteht noch Handlungsbedarf in der Praxis, um das Wissen zur richtigen Anwendung von Risikomanagementinstrumenten zu vertiefen, da die richtige Anwendung der Instrumente essentiell ist für die Effizienz der

Instrumente. Zukünftige Arbeiten sollten sich mit einem möglichen Anreizsystem beschäftigen, damit Landwirte und Berater diese Plattform auch entsprechend nutzen.
Sowohl bei der finanziellen Unterstützung für die Erzeugerorganisationen als auch bei der finanziellen Förderung der Risikomanagementinstrumente wäre in einer zukünftigen Gemeinsamen Agrarpolitik mehr Flexibilität notwendig. Die Forderung seitens der Copa-Cogeca, die gewährten Gelder für die anerkannten Erzeugerorganisationen auch für Personalgehälter verwenden zu können, ist ein sinnvoller Reformvorschlag, da die Ausbildung und der Erfolg einer Erzeugerorganisation stark zusammenhängt, wie die Studie „Erfolgsstrategien von Obst- und Gemüsegenossenschaften im Zuge der Internationalisierung des Hortibusiness“ (Gandorfer et al., 2016) zeigt. Insbesondere bei der Subventionspolitik für Hagel- und Frostrisikomanagement können in Deutschland bislang nur technische Maßnahmen (Hagelnetz, Frostberegnung) gefördert werden. Standortabhängig sind aber technische Maßnahmen nicht immer die beste Wahl für einen Betrieb. Die Frostversicherung wird aufgrund der hohen Prämien bislang in Deutschland nur in sehr geringem Umfang genutzt. Durch eine zeitweise Subvention könnte sich der Pool der Versicherten vergrößern und damit die Prämien insgesamt reduziert werden. Im Rahmen der Gemeinsamen Agrarpolitik sollte den Produzenten deshalb mehr Flexibilität bei der Verwendung der Mittel eingeräumt werden.

Summary

Although fruit and vegetables are only cultivated on 1.3% of the agricultural production area, horticulture plays an important economic role in Germany. In recent years, this sector has been confronted with many challenges, such as yield losses due to extreme weather events or low producer prices due to the Russian import ban. However, horticulture has only played a minor role in agricultural risk management literature to date. In this dissertation, the risk management process of small and medium-sized horticultural farms is examined holistically using German fruit farms as an example. Key issues such as assessing risks for fruit farms and risk management instruments as well as deriving the need of new instruments or political action are the core of this dissertation.

The existing risk management literature in agricultural economics research offers a variety of methods for risk and risk management instrument assessment. These can essentially be categorized into quantitative (approaches with objective probabilities), semi-quantitative (approaches with subjective probabilities) and qualitative (e.g. cognitive mapping; not in the focus of this work) research. Quantitative approaches are predominantly used in the existing literature, although this has increasingly provoked criticism in recent years. Points of criticism particularly concern the data requirements and data availability, the necessary methodological competence and the resulting limited practical suitability, or the concentration on risks that can be measured but may not be decision-relevant.

In order to work on the objectives of this work, the individual approaches were compared with each other, based on which the following comparison criteria were identified: research question (specific to holistic), period of data collection, data requirements, availability of data, time for data collection, as well as causes for possible biases. From this, the appropriate methods for the research questions of the dissertation were identified and the results from the use of quantitative and semi-quantitative approaches were compared with each other.

In the first part of the dissertation, the risk management process was surveyed and analyzed using 105 German fruit growers as an example. The online survey comprised three parts: elicitation of risk attitudes, analysis of the risk management process and collection of socio-demographic data. The key messages of the study can be summarized as follows: both methods for measuring risk attitudes (self-assessment, business-related statements) show a bipolar distribution, although there is only a weak correlation between the results of the two methods. The weak correlation confirms the situational dependency of risk attitudes. Existing risk models should be adapted by also including risk-neutral and risk-seeking decision-makers to take into account the bipolar distribution of risk attitudes.

As expected, production and price risks are the most important risk categories, followed by personal, cost, marketing, asset and financial risks. Within the risk categories, there is a high degree of conformity on the assessment of the individual risk sources, whereas the assessment of single risks within the price risk category is highly dependent on the individual farm. The main causes of the production risk are hail and frost. The results also show a strong correlation between the loss experience and the risk assessment, which may indicate a possible bias. The most important risk management strategy is diversification, whereby the diversification of crops, marketing channels and additional farm income play an important role. The analysis also shows that there is a high degree of satisfaction with the diversification, especially regarding marketing channels. Between hail insurance and anti-hail nets, there is a large discrepancy in terms of use and satisfaction with the instrument applied. It is remarkable that 16% of the farms surveyed use both anti-hail nets and hail insurance. The people risk is underestimated, which becomes obvious when analyzing the assessment of the single risk sources within this category. The fruit producers interviewed differentiate between personal risk – which affects the farm manager and family workers – and personnel risk, which affects employees and seasonal workers. Insurance policies (accident insurance, life insurance) are mainly used to cover themselves and family workers. Internal instruments such as the documentation of work processes or the issuing of a general power of attorney for emergencies are important instruments for risk management, although they are not yet widely used in practice. In order to reduce the personnel risk, farm managers focus on employee satisfaction and early arrangements. More attention should be paid to this risk category in future research, particularly concerning issues such as farm succession, the internal emergency plan or the legal requirements for the employment of seasonal workers from third countries.

In the second part of the dissertation, using an expected utility approach (quantitative approach) different options for managing hail risk were analyzed. The basis for the study was a ten-year, orchard-specific time series of insurance data. The aim of the study was to identify the strategy with the highest benefit for the fruit producer, depending on local hail risk, yield potential, the financial situation of the farm and the risk attitude. A total of 105 orchards were examined, which can be assigned to four groups. Independent of the risk attitude, for the first group (low hail risk, low yield potential) it is most efficient if no risk management instrument is used. In the second group (high hail risk, low yield potential), hail insurance is the most efficient instrument. The results are not influenced by the risk attitude. For the third group (low hail risk, high yield potential), anti-hail nets are the most efficient option for the risk-neutral to slightly risk-averse fruit producer, although there is a shift to hail insurance with increasing risk aversion. The reason for this effect lies in the hedging costs: in the case of anti-hail nets, the costs per ton of yield decrease, although they are always constant in view of the local hail risk.

In the case of hail insurance, hedging costs increase as the local hail risk increases and the yield increases. In years with low yields, the insured sum can be adjusted, while the costs for the anti-hail nets remain constant. This flexibility is a major advantage of hail insurance compared with anti-hail nets. In the fourth group (high hail risk, high yield potential), anti-hail nets are always the most efficient instrument, regardless of initial wealth and risk attitude. Combining these results with the satisfaction analysis from the first study, it can be concluded that despite frequent use, hail insurance is not the most efficient risk management instrument for every farm. When deciding between the installation of an anti-hail net or purchasing hail insurance, the marketing channels as well as the cultivated varieties should be taken into account additionally.

In the third part of the dissertation, the diversification of marketing channels and crops were examined as a price risk management strategy. Using nine-year producer price time series for different fruit and vegetable crops, the various marketing channels were examined regarding the volatility of producer prices. Only apple and strawberries showed a significant difference in producer price volatility. In all cases, marketing via the wholesale market is much less volatile than marketing via the producer organization. There has been no significant increase in producer price volatility over the past nine years; however, in individual years there have been price shocks, e.g. due to weather events or political crises. By diversifying marketing channels, price risk can be managed, provided that there is access to several marketing channels. The results of the first study also showed that the fruit producers surveyed are very satisfied with the diversification of marketing channels. However, since not every producer has access to several marketing channels, there is still a need for new, innovative instruments for managing price risk.

In the present dissertation, quantitative and semi-quantitative approaches were combined to evaluate price and production risks as well as risk management instruments. The results showed that the studies using different approaches complement each other. For this reason, an integrated risk management approach should be established, especially for small and medium-sized farms: the subjective assessment of risks and risk management instruments represents an appropriate procedure for dealing with missing data or risks that cannot be quantified. The combination with quantitative approaches limits the risk of biases (e.g. heuristics) and can thus contribute to optimizing operational risk management. For fruit producers, a risk management process developed as part of this dissertation should be integrated into farm management systems in the form of a module. It is important that the farm management systems contain all relevant operational information in the future, from the documentation of plant cultivation to the risk management module.

Finally, the current proposals for the Common Agricultural Policy after 2020 were analyzed regarding their relevance for horticulture based on the present results. The proposals can be divided into six subject areas: retention of the existing financial support, knowledge transfer, producer organizations, subsidization of risk management instruments, price transparency and market power of food retailers. In particular, the European Commission and the interest groups analyzed (Copa-Cogeca, Bavarian Farmers` Association) agree on maintaining financial support and strengthening producer organizations, as these two areas certainly represent the greatest benefit for farms.
Knowledge transfer is a central aspect of the European Commission's. The European Commission proposes a platform on which knowledge of and experience with existing risk management instruments can be shared. The European Commission also sees this platform as an opportunity to obtain information on the need for additional instruments. The platform is intended for farmers, consultants and politicians. As the results of this dissertation show, there is still a need for more information about the functions, because the appropriate use of the instruments is essential for the efficiency of the instruments. Future research should investigate a possible incentive system so that farmers and consultants will use this platform accordingly.
More flexibility would be desirable in a future Common Agricultural Policy, in terms of both funds for producer organizations and financial support for the use of the risk management instruments. Copa-Cogeca's demand that it should also be possible to use funds granted to recognized producer organizations for staff salaries is an important request, as the study “Success factors of fruit and vegetable producer organizations in the course of internationalization of the hortibusiness” (Gandorfer, 2016) has shown that the training and success of a producer organization are closely linked. At present, only technical instruments for hail and frost risk management (anti-hail net, frost irrigation) can be subsidized according to German policy. However, depending on the location, technical instruments are not always the best choice for a farm. Frost insurance is currently only used to a very limited extent in Germany due to the high premiums. A temporary subsidy could increase the pool of insured farmers and thus reduce premiums overall. The Common Agricultural Policy should thus give producers more flexibility in the use of the funds.

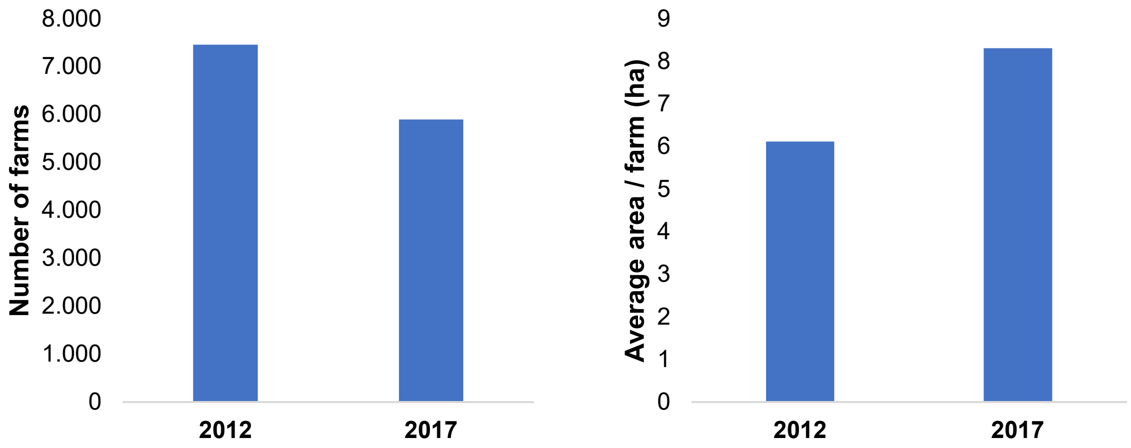
1 Introduction

Despite only occupying 1.3% of the total agricultural production area (Destatis, 2018 a, b, c, d, e), German fruit and vegetable farms generated approximately 3.5 billion Euros of turnover in 2017, which is equivalent to 6% of overall German agricultural production (DBV, 2018, p. 150). The fruit and vegetable sector is thus an important industry within the German agriculture sector. However, in recent years this sector has faced several challenges, e.g. “the approval of the minimum wage in Germany, low producer prices due to the Russian import ban, yield losses due to weather extremes and food scandals” (Porsch et al., 2018a, p. 10). With the forthcoming Brexit process, fruit and vegetable producers are confronted with a further challenge, because “the United Kingdom imports products from the EU-27 at a value almost equivalent to that of EU exports to third countries” (CC, 2018, p. 2). These developments show the importance of an appropriate risk management for German fruit and vegetable farms. Although risk management has been one of the most important topics in agricultural economics research in recent years, fruit and vegetable farms have received little attention to date (e.g. Martin, 1996; Röhrig and Hardeweg, 2014; Vassalos and Li, 2016; Hartwich et al., 2015; Salk et al., 2007; Porsch et al., 2018a). However, a closer insight into the risk management process of fruit and vegetable farms is necessary because there are fundamental differences between horticultural and agricultural farms, thus impeding the transfer of findings of the existing risk management literature.

1.1 The relevance of risk management in the fruit and vegetable sector

Structural change is one of the most important drivers for the increasing importance of risk management in agriculture (Liebe et al., 2012). This trend can also be seen in the fruit and vegetable sector (Steinborn and Bokelmann, 2007). The number of fruit farms decreased from 2012 to 2017 by 21%, whereas the average area per farm increased by 36% (see **Figure 1**). Accordingly, especially small farms have ceased fruit production (see also Hartwich and Gandorfer, 2014).

According to Steinborn and Bokelmann (2007), a higher share of rented land, a higher production intensity and high investments have accompanied this farm growth. Hartwich et al. (2015) deduced that this development caused increasing cash-based costs and thus a decreasing risk-bearing capacity of these farms. The risk-bearing capacity is important to access loans and secure a low interest rate (Bahrs et al., 2004; Frentrup et al., 2014).



Note: Since 2017 the category "other tree fruits" is also included in the statistics. To be able to compare the years 2012 and 2017, the category "other tree fruits" has been removed from the total figures for 2017.

Figure 1. Structural change in fruit production (Data source: Destatis, 2017)

Porsch et al. (2018a) found many differences in the farm key characteristics between horticultural and agricultural farms, which are important to know especially in terms of the risk-bearing capacity of the farms: for cash crop and dairy farms, direct payments still play an important role for income stabilization, with a share of profits of 57% and 77%, respectively. By contrast, the impact of subsidies in horticulture is low: subsidies contribute only 16% to the average fruit farms' profits, and for vegetable farms this share is even smaller at 7%. Another important difference relates to production costs: fruit and vegetable production is very capital-intensive, whereby labor costs (i.e. seasonal workers and non-family workers) amount to 23% and 25% of total production costs, respectively. Vegetable and cash crop farms can make decisions regarding crops and varieties on an annual basis. A special feature of fruit farms is that most fruits are perennial crops. In view of risk management, this is crucial in two aspects: there is no yield in the first years after planting; and fruit production is a long-term investment decision, indicating a lower entrepreneurial flexibility compared to agricultural farms (Weis, 2007). Therefore, the focus of this thesis lies on fruit production.

Most fruit farms are family-run businesses. Especially for these farms, the implementation of a risk management process remains a challenge, because they have usually not enough resources for this task (Reynolds-Allie et al., 2013). Because small and medium-sized family-run fruit businesses are typical of most agricultural systems, analyzing the needs of these farms is important.

1.2 Important risk sources in German fruit production

According to Mouron and Carint (2001), the economic success of a fruit farm comprises three key factors: the producer price of highest quality class, the share of the highest quality class and the yield. The high relevance of yield and the producer price are confirmed by Hartwich et al. (2015), examining the influences of different risk sources on the revenue volatility of different fruits and vegetables. Production and price risk explain between 10% and 90% of the revenue volatility, depending on the crop (Hartwich et al., 2015). Due to the ongoing concentration process of the food retailing sector and the increased competition within the EU market, price risk is gaining increasing importance (Flenker et al., 2009; CC, 2018).

The yield as well as the yield quality strongly depend on weather conditions. The most important weather-related production risks in fruit production are late frosts as well as hail (Gömann et al., 2015). Over the last 30 years, both the frequency and extent of hailstorms have increased in Central Europe (Kunz et al., 2009; Mohr and Kunz, 2013), with southern fruit-growing areas in Bavaria and Baden-Wurttemberg being particularly hard hit (Kunz and Puskeiler, 2010; Mohr and Kunz, 2013). Due to the early flowering of many specialty crops, the late frost risk is also increasing (Chmielewski and Blümel, 2013).

Finally, political risk should not be underestimated in fruit production, as many examples in recent years have shown, including the approval of the minimum wage, new pesticides directives, the Russian import ban and the recent Brexit referendum.

An initial analysis of the risk management instruments (Hartwich and Gandorfer, 2014) showed that fruit production is mainly dominated by on-farm risk management instruments (Deunick et al., 2008). In terms of price risk mitigation, on-farm risk management instruments include a diversification of marketing channels (Mencarelli-Hofmann, 2009), post-harvest storage (Hirschauer and Mußhoff, 2012), extension of the harvest period (Dierend et al., 2009) and selling via recognized producer organizations (Steinborn and Bokelmann, 2007). For production risk management, common on-farm risk management instruments are frost irrigation, hail canons, anti-hail nets, irrigation, canopies, variety choice (Regklam Konsortium, 2013), foils and fleeces (Dierend et al., 2009), prophylactic plant protection and the use of pest forecast models (Samietz et al., 2007). External instruments for risk mitigation are only available to a limited extent. In contrast to most of its European neighbors, in Germany only unsubsidized hail and frost insurances are available. Important instruments to mitigate price risk – e.g. post-harvest storage or commodity markets – are not or only partly available in fruit production. Post-harvest storage is only suitable for some fruits due to their perishability and commodity markets do not exist (Manfredo and Libbin, 1998; Belasco et al., 2013).

1.3 Risk management in (agricultural economics) literature

The following section provides an overview of the theoretical and conceptual foundation of the studies presented in this dissertation. The first part of this section provides an overview of the risk management process, which can be seen as the theoretical framework to which each study in literature can be assigned. In the second part, a description of the main methods to identify and assess risks is provided. In the third part, an overview of the main methods employed to assess relevant risk management instruments is provided, before the aims and objectives of this dissertation are presented in the fourth part. Finally, the methods applied in the different studies of this dissertation are discussed.

1.3.1 The risk management process

The risk management process presents a framework for the analysis and management of risks (see **Figure 2**). This framework comprises three steps: risk analysis (risk identification and assessment), risk mitigation and control (Wolke, 2008).

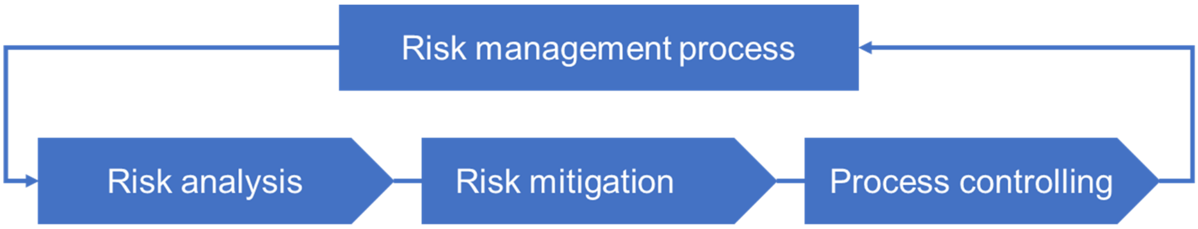


Figure 2. Risk management process (see Wolke, 2008)

The main goals of the risk management process are to identify risks, reduce income fluctuations and identify opportunities and competitive advantages. The risk identification and assessment are the basis for the risk management process (Wolke, 2008). The classification of risks into business and financial risks is a common category in literature. Business risk includes the risk categories of production risk, price risk, cost risk, marketing risk, asset risk and political risk. Financial risk results from the commitment to meet payment obligations, regardless of how the operating income develops (Mußhoff and Hirschauer, 2016). Financial risk is closely linked to the risk-bearing capacity of the farm.
The term risk refers to the deviation from a target variable (e. g. gross margin, profit, or income) (Schulte, 1997). After the relevant risks have been identified, the appropriate risk management instruments are chosen. The last step is the process control, in which the efficiency of the applied risk management instruments is assessed.

1.3.2 Comparison of different approaches within the risk management process

The agricultural economics literature contains many approaches for analyzing risks and risk management instruments. These can essentially be divided into two categories, namely quantitative and qualitative approaches (e.g. Peeler et al., 2015; VanWinsen et al., 2013; Akimowicz et al., 2018), "depending on how likelihood is estimated" (Peeler et al., 2015, p. 483). Within quantitative approaches (in other studies, also called rational approaches or approaches using objective probabilities, see e.g.; Hardaker and Lien, 2010; VanWinsen et al., 2013), the probability of occurrence (=likelihood) and the exposure of the risk are "expressed numerically" (Peeler et al., 2015, p. 483). These approaches therefore require that the studied risk is "well-defined, independent, quantifiable and comparable" (VanWinsen et al., 2013, p. 42). In agricultural economics risk management literature, the assessment of risks and possible instruments to mitigate risk is predominantly conducted with quantitative approaches.

However, Hardaker and Lien (2010) criticized that these assumptions are highly simplified, which leads to a general focus on risks that can fulfill these requirements, irrespective of whether this risk is truly important for the farm (Hardaker and Lien, 2010). Furthermore, there is often a mismatch between the research results on assessment of risks and risk management instruments and the real risk perception and real risk behavior of farmers, indicating that farmers do not always act as rational decision-makers (VanWinsen et al., 2013). For these reasons, an increasing number of studies have been conducted in recent years focusing on "qualitative approaches" (e.g. Barodte, 2008). Within these approaches, the probability of occurrence (=likelihood) and the exposure of the risk are "expressed using non-numerical descriptions such as high, medium, low or negligible" (Peeler et al., 2015, p. 483). However, to draw a distinction here from qualitative research, which uses cognitive mapping or mental mapping in the context of risk analysis – for example – but is more concerned with contexts and open questions but less with probabilities, the terms "semi-quantitative" (Peeler et al., 2015) or "subjective probabilities" (Hardaker and Lien, 2010) are used. In addition to the different measurement of probability, there are other distinguishing characteristics between the different approaches (see **Table 1**).

Table 1. Differences between the research approaches (Just, 2003; Hardaker and Lien, 2010; VanWinsen et al., 2013; Barodte et al., 2008; Barodte, 2008; Menapace et al., 2012a; Akimowicz et al., 2018)

	Quantitative approaches	**Semi-quantitative / qualitative** approaches
Research question	Specific	Specific to broad / holistic
Period of data collection	Several years	At one point (“snapshot”)
Data	Enumerative, well-defined, independent and comparable	All categories
Time of data collection (for research)	Low (in most cases secondary data)	High (in most cases primary data)
Data availability in farms	Limited to not at all	Available or ascertainable
Bias	Due to data aggregation level	Due to heuristics

1.3.3 Overview of methods for risk analysis

Within risk analysis, there are three major areas of work in risk management research:

- Risk analysis using approaches with objective probabilities
- Risk analysis using approaches with subjective probabilities or subjective rating
- Factors influencing the risk analysis

Approaches with objective probabilities are characterized by using objective and measurable data. Probability distributions serve as the decision baseline for economic questions. Exemplary methods for risk assessment with objective probabilities are the volatility, the value at risk or the extreme value theory. According to Gilbert and Morgan (2010), volatility is a directionless measure of the extent of the variability of a variable (e.g. price or revenue). For analyzing the volatility, Huchet-Bourdon (2011) proposed different measures, e.g. the coefficient of variation, the corrected coefficient of variation or the standard deviation of the logarithm of prices in differences. The value at risk is a quantile of the loss function: the value at risk at a given probability level indicates the loss amount that will not be exceeded within a given period with this probability (Odening and Mußhoff, 2001). The extreme value theory deals with the analysis of maximum and minimum values of a sample and determines the probability that these values will occur.

There are some studies conducting an objective risk assessment in fruit production. Mouron and Scholz (2008) evaluated the income risk of apple producers in Switzerland over a four-year period depending on different management procedures. The authors determined the net income per labor hour as a target variable and assessed the income risk based on the arithmetic mean, the standard deviation and the skewness. They ascertained that most of the analyzed farms "were able to turn the apple production system from a system with unlimited losses to one with limited losses, by avoiding very low-income cases" (Mouron and Scholz, 2008, p. 65). Therefore, success factors were strong knowledge on production technology (e.g. the use of hail nets, hail insurance, pesticides, fertilizers, etc.) as well as investment in pre-harvest working hours (Mouron and Scholz, 2008). According to the authors, a main limitation of their work comprises the limitation of the observation period (four years).

Waibel et al. (2001) used extreme values (extreme value theory) to investigate how the business risk of a fruit farm changes when converting to ecological farming. They ascertained that essentially the conversion to organic farming is profitable also under the consideration of price and production risk. The apple variety Topaz – which is scab-resistant – is dominant above all other studied varieties (Pinova, Elstar and Jonagold). The authors concluded that with increasing annuity, the diversification in crop varieties decreases and at a high annuity only Topaz should be cultivated.

Chen et al. (2007) also analyzed the income risk of organic and conventional apple farms in the Pacific Northwest in the US. They found that producing apples organically is always riskier compared with producing conventionally. As key figures for risk assessment, they used the coefficient of variation. However, the authors concluded that the risk in organic production mainly depends on the variety, thus confirming the findings of Waibel et al. (2001). According to the authors, a limitation of their study related to the low availability of data on the organic farms.

Wang et al. (2010) used the value-at-risk concept to assess price risk for selected fruits and vegetable crops. In their study, Wang et al. (2010) distinguished crops with high (e.g. strawberries and watermelons), medium (e.g. grapes and oranges), and low price risk (e.g. apples, bananas and pears). Crops with a low price risk are characterized by the fact that they are available all year round, can be stored and are easy to transport. Crops with a medium price risk have similar characteristics but are marked by sales cycles. By contrast, crops with a high price risk are hardly storable and characterized by strong seasonality. For these crops, high prices can mainly be obtained at the beginning and end of the harvest time, while prices are very low during the main harvest time.

As the examples (summarized in **Table 2**) illustrate, the objective assessment of risks requires a high degree of data availability and the prerequisite of quantification must be fulfilled. However, these requirements are not always available in practice (e.g. Hardaker and Lien, 2010; VanWinsen et al., 2013).

An alternative is the use of approaches assessing risk with subjective probabilities (= risk perception) (Wocken et al., 2008; Hardaker and Lien, 2010). One method within the approaches involving subjective probabilities is priority analysis, through which the risks can be ranked according to their importance (Böhm and Henning, 1997). Martin (1996) used priority analysis and interviewed fruit producers (kiwi and pome fruit) in New Zealand in terms of how they assess different risks (ranking on a scale of 1 to 5, whereby 1 = not important for the farm and 5 = very important for the farm). She ascertained that price risk played the most important role. In their study, Anderson et al. (2013) investigated the damage caused to fruit producers by bird herbivore damage. In order to assess the risk, producers were asked to indicate how much they estimate the annual losses caused by bird herbivore damage and what bird species cause the greatest damage to farms. These should be ranked according to their significance. Crops under study were apples, blueberries, cherries and wine grapes. The study was conducted in California, Michigan, New York, Oregon and Washington. The authors ascertained that the American Robin, the European Starlin and Blackbirds caused the highest damages, whereby the ranking of these three species depended on the individual crop. The annual losses per hectare and state amounted to between 299 and 7.267 dollars for apples, between 1.609 and 4.571 dollars for blueberries, 230 and 946 dollars for wine grapes, between between 746 and 2.417 dollars for sweet cherries and between 104 and 3.042 dollars for tart cherries.

In addition to the priority analysis, the concept of the risk matrix is often used in risk management literature to highlight the relevance of individual risks for a company (independent of the industry). Within this approach, a risk source must be assessed on a Likert scale based on two criteria: the perceived probability of occurrence and the assumed extent of damage (Peeler et al., 2015). The risks can then be displayed in two dimensions, in which the values for the perceived probability of occurrence are plotted in a coordinate system on the x-axis and the values for the assumed extent of damage are plotted on the y-axis. The location of the risks can thus be used to determine the relevance of each risk (the higher on the y-axis and the more located to the left on the x-axis, the more relevant it is for the company) (Wocken et al., 2008; Quinn et al., 2003; Smith et al., 2000). Gömann et al. (2015) analyzed relevant weather-related risk sources for German fruit growers surveying consultants on the importance of weather risks. They found that hail and frost are the most important risk sources in apple production. Depending on the region, hail and frost alternate between first and second place. In northern Germany, flooding is the third most important risk, whereas in southern Germany drought occupies this place. Röhrig et al. (2018) uses the fixed value method to assess hail risk. Therefore, participating farmers in their survey were given a table with loss ratios (0%, 1-4%, 5-9%, …) and were asked how often hail lead to the presented losses. Therefore, farmers should allocate ten years to the presented intervals. The identified studies using objective and subjective probabilities are summarized in **Table 2**.

The subjective assessment of risks provides many advantages compared to the objective risk assessment, e.g. the possibility to assess risks that are not measurable or for which insufficient data is available. However, a disadvantage of subjective risk assessment is that subjective assessments can be biased by various factors (assessment anomalies). These assessment anomalies originally played a role in the risk perception research, particularly regarding consumers, although they have also recently gained importance in entrepreneurial risk research, particularly regarding financial management (Wocken et al., 2008). Causes for evaluation anomalies can include heuristics, as "rules of thumb" that are used to make decisions when the level of information is incomplete. There are various heuristics, the best known of which are the availability heuristic and the representativeness heuristic. The availability heuristic can be used in situations where the probability of an event must be assessed: the retrieval of information from memory varies in effort. The probability of occurrence of the risk to be evaluated is deduced from the effort associated with retrieving the information from memory (Tversky and Kahnemann, 1974). The representativeness heuristic is used to estimate the probability of occurrence of a risk that is less known. Therefore, a familiar event – which is comparable to the risk to evaluate – is used to assess the probability of occurrence (Menapace et al., 2012b). A further reason for bias in subjective risk assessment is schemes or frames (Tversky and Kahnemann, 1974). For example, whether a decision situation is viewed from a loss or profit perspective plays an important role. Generally, losses are estimated to be higher than profits. Menapace et al. (2012b) studied the subjective risk perception of fruit and wine growers in the Province of Trento (Italy), whereby they focused on assessing two production risks (apple: hail and shoot dieback; grape: hail and mildew) and their change due to ongoing climate change. The authors analyzed whether the assessment of the long-term effects of these risks is based on heuristics. In order to investigate the availability heuristic, it was assumed that farmers who had experienced severe hail/illness damage in the past estimate the probability that the respective risk will occur in the future (because of progressive climate change) as being higher. In order to investigate the heuristic of representativeness, information on the short-term development of individual risks (e.g. change in the number of hail days in recent years) was provided. With this information, the respondents were asked to assess whether the respective risk will increase in the future. The results of the study showed that fruit and wine producers use heuristics to assess the long-term effects of climate change on production risks. In another study, Menapace et al. (2012a) examined whether there is a correlation between personal risk attitudes and risk assessments. The study found that farmers with high risk aversion estimate possible yield losses to be significantly higher than those

Table 2. Overview of studies analyzing risks in fruit production

Risk	Method	Data	Approach	Fruit	Location	Finding	Study
Income risk	Coefficient of variation	Time series yield data, price data, APH records, production costs, survey data	Quantitative	Apple	USA	Organic apple production showed higher income risk compared to conventional production. Income risk depends strongly from on variety.	Chen et al. (2007)
Income risk	Skewness, standard deviation	Four-year time series of 445 annual orchard results	Quantitative	Apple	Switzerland	All studied farms can reduce downside risk. The production know-how and the pre-harvest work have a decisive influence on the income risk.	Mouron and Scholz (2008)
Income risk	Extreme value	Survey data of 18 fruit farms; Monte Carlo Simulation	Quantitative	Apple	Germany	Organic farming faces a higher risk compared to conventional farming The choice of variety is particularly important for reducing the income risk.	Waibel et al. (2001)
Income risk	Sensitivity analysis	Official statistics	Quantitative	Apple, pear	Argentine	Labor availability has an important influence on the profitability of a pome fruit farm.	Catalá et al. (2013)
Price risk	Value at risk	Nine-year time series of wholesale market prices	Quantitative	Apple, orange, banana, pear, grape, watermelon and strawberry	China	Different groups of fruits have been identified according to their price sensitivity. Identification of characters describing the individual group.	Wang et al. (2010)
Production risk	Fixed value method	Survey data of 134 apple growers	Semi-quantitative	Apple	Germany	Yield losses due to hail are measured with the fixed value method.	Röhrig et al. (2018)
Risk sources of fruit farms	Priority analysis	Survey data of 158 fruit growers	Semi-quantitative	Kiwifruit, pip fruit	New Zealand	Risk sources have been ranked in terms of their importance for fruit farms. Price and production risk are the most important risk sources.	Martin et al. (1996)
Production risk	Priority analysis	Survey data of 89 fruit growers	Semi-quantitative	Apple, blueberry, cherry and wine grape	USA	Different bird species are ranked according to their risk potential for yield losses.	Anderson et al. (2013)

with lower risk aversion. The individual assessment of risks depends on many factors. An important role in the evaluation is played the characteristics of the farm manager, e.g. his/her risk attitude, age, education or gender (e.g., Ihli et al., 2012; Koesling et al., 2004; Schaper et al., 2010; Menapace et al., 2012a). Moreover, the farm characteristics can influence the subjective risk assessment. Examples include whether the farm is managed full or part time, as well as organic or conventional production (Medina et al., 2007; Lien et al., 2006). The characteristics of the risk itself also play a role in the assessment (Schütz and Peters, 2002).

1.3.4 Overview of methods for risk mitigation and control

Risk management instruments can be divided into four strategies: avoid, cope, minimize and transfer (Wolke, 2008). In this step of the risk management process, the use of risk management instruments and their efficiency (e.g. lower variance of the target variable, lower amount of loss) are measured.

There are essentially three major areas of work in risk management research in this respect:

- Development of risk management instruments
- Evaluation of risk management instruments
- Analysis of risk behavior and influencing factors

The development of risk management instruments primarily focuses on insurance and weather derivatives. It is noticeable that – in comparison to classical cash crops – there are comparatively few external risk management instruments for specialty crops available (Richards and Mischen, 1998). The main reasons for this are the lack of data availability (due to the limited growing area of specialty crops) for calculating insurance rates and the problems of moral hazard and adverse selection inherent in insurance (Richards and Mischen, 1998). Belasco et al. (2013) also added that for the insurance system in the US the missing future and option markets are one reason for the lack of insurance schemes for specialty crops, because these markets are used to "establish price guarantees" (Belasco et al., 2013, p. 404).
Fleege et al. (2004) analyzed the performance of weather derivatives in managing risks of specialty crops in California. The authors used the Sharpe ratio, the value at risk and the certainty equivalent as risk measures to assess whether the risk could be reduced using weather derivates. They conducted an analysis of different fruit crops (nectarines, raisin grapes, and almonds) and different hedging strategies (put option, call option and straddle). They found that in general weather derivatives can be effective instruments to reduce net income risk. However, the effectiveness of weather derivatives strongly deviated depending on the price-yield correlation: the lower the correlation between price and yield, the more efficient the analyzed weather derivatives. Crops that cannot be stored and perish quickly can benefit from the natural hedging effect (lower yield, higher price due to a lower supply). This means that the

loss of yields is compensated or even over-compensated by a higher price. In this case, the additional risk management costs (for the weather derivative) lead to an inefficient risk management strategy.

Comparing the income risk of organic and conventional apple production, Chen et al. (2007) scrutinized how efficient yield insurance and a hypothetical revenue insurance are in terms of reducing income risk. They found that the revenue insurance is not preferable to the existing yield insurance, because the provided price selection (specified by the insurance company) is insufficient compared to the market cash price. Regarding the existing yield insurance, organically-producing farmers benefit more from insurance than conventionally-producing ones, given that the income risk is inherently greater. Overall, in most scenarios the premium amount is excessive in relation to the risk of the individual grower, despite subsidies.

Belasco et al. (2013) compared yield insurance with high tunnels to reduce weather-related risks in strawberry production in a field experiment. They used the yield variability and the expected profits as key figures to assess the different risk management strategies. Their results showed that high tunnels can increase expected profits and reduce yield variability. Comparing crop insurance and high tunnels, Belasco et al. (2013) stated that “while crop insurance provides a safety net for farmer revenue, high tunnels shift and shrink distributions of yields while positively affecting price premiums” (Belasco et al. 2013, p. 416). The authors listed two further arguments in favor of high tunnels: in contrast to subsidized insurance programs, high tunnels are a risk management instrument enabling small-scale producers to maximize profits “without the use of government payments” (Belasco et al., 2013, p. 416) and they are thus much less dependent on current policy; moreover, a further advantage is the longer harvest period of crops cultivated in a high tunnel, which enables farmers to obtain high off-season prices. As the shelf life could be increased in past high tunnel experiments, Belasco et al. (2013) estimated a low risk that higher prices would fall with an increasing number of farmers using high tunnels.

Ho et al. (2018) examined different risk management strategies (high tunnels, crop insurance, and weather insurance) for small and medium-sized sweet cherry producers in Michigan and New York State. The authors used several criteria – e.g. expected net returns, coefficient of variation and distribution of net returns – to compare high tunnels, crop insurance and weather insurance (frost insurance, harvest rain insurance). They found that all risk management scenarios (insurances, high tunnels) are improvements compared to the status quo (no risk management).

For the two main apple production areas in Germany (Lake Constance and Elbe region), Röhrig et al. (2018) compared different strategies of managing weather-related risks (hail and frost). For the northern production area, they compared hail insurance with the alternative of no risk management. For the southern production area, they compared the risk management instruments of anti-hail nets and hail insurance. The authors found that for all scenarios (different apple varieties and plant densities) and across all levels of risk aversion, the certainty equivalents of the hail insurance were smaller than those of the anti-hail nets.

The analysis of risk behavior provides information on how farmers decide in practice, thus making it possible to examine the need for instruments. Various studies on risk behavior can be found in agricultural economics research for classical agricultural producers (cash crops, livestock). For example, Szèkely and Palinkas (2009) compared how European and American farmers differ in terms of the risk management tools used. Von Alten (2008) investigated the risk behavior using the example of the introduction of multiple risk insurance and the factors on which the choice of instrument depends. Lien et al (2006) examined the risk management of full- and part-time businesses and found some significant differences in the choice of instruments. Koesling et al. (2004) also found differences in risk behavior in organic and conventional farms. Risk behavior depends on many factors, which can essentially be divided into three groups. The first group comprises the characteristics of the farm manager, such as risk attitude, age and training (e.g. Koesling et al., 2004; Schaper et al., 2010; Pennings and Leuthold, 2000). The properties of the instrument also play an important role, with several studies having concluded that the complexity of the instrument plays a role in its practical application (e.g. Salk et al., 2007; Liebe et al., 2012). Finally, operational characteristics such as the debt-to-equity ratio, business orientation and the risk instruments already used play a role (e.g. Dean and Malcom, 2006).

Independent of the research approach (quantitative, semi-quantitative, qualitative), it is important to consider the risk-bearing capacity in terms of the choice of risk management instruments. The risk-bearing capacity describes the financial loss that a company can bear without encountering a financial crisis. Due to various trends in the horticultural sector – such as the increasing share of leased land and the increasing use of employees – the consideration of risk-bearing capacity regarding operational risk management is becoming increasingly important. After all, risk-bearing capacity is decisive for risk assessment and the choice of instruments for risk management in the operational context: the less equity and financial reserves that a company has, the sooner a risk must be assessed as relevant and the more important it is that the company must use risk-reducing measures (Frentrup et al., 2014; Brand-Saßen, 2009).

1.4 Aims and objectives of the dissertation

Although risk management is a crucial topic in fruit and vegetable production, there is a research gap in the agricultural economics literature. Using the example of fruit production, the major aim of this study is to close this gap and provide well-founded insights into the risk management of fruit farms for farmers, consultants as well as politicians. Furthermore, the dissertation aims to identify the need for new risk management instruments or political action to support new and existing risk management measures and instruments. In the first part of the dissertation (**study 1**), the aim was to conduct an analysis of the entire risk management process in small and medium-sized fruit farms, including the identification of relevant risk sources and the risk management applied, as well as analyzing the level of satisfaction with the instruments applied. The analysis detected the two major sources of risk in fruit production: hail risk and price risk. Building on the results of the first study, the second study (**study 2**) aimed to investigate different risk management strategies to offer recommendations for an optimal risk management strategy to mitigate hail risk depending on farm-specific conditions. In the third study (**study 3**), the aim was to investigate producer price volatility for different crops and marketing channels to achieve knowledge about appropriate diversification strategies. In view of the Common Agricultural Policy after 2020, the results of the three studies are compared and with these insights the reform proposals of the European Commission and selected interest groups have been assessed.

In order to conduct an analysis of the entire risk management process of German fruit farms (**study 1**), the objectives were to: 1) develop a framework; 2) gather data concerning how farmers perceive risks and how they mitigate risks; 3) investigate the satisfaction with the applied instruments; and 4) to analyze whether risk attitude influences risk perception and the use of risk management instruments.

As the results of the first study showed, hail risk is one of the most important risk sources in fruit production. In order to determine the preferability of different strategies, a detailed risk analysis comparing different strategies to manage hail risk – depending on the orchard-specific hail risk, yield potential, farm wealth and risk attitude – was conducted in **study 2**. Ultimately, the study's objective was to derive recommendations for the optimal hail risk management strategy.

The third study`s (**study 3**) objective involved identifying differences in producer price volatility among marketing channels, as well as examining whether producer price volatility has increased in the past decade.

1.5 Data and methods

For the first study, an online survey with German fruit producers was conducted in 2014. Although 263 questionnaires were registered in the online survey tool, only 105 questionnaires could be used for the analysis due to a high drop-out rate. The participants of the survey are fruit growers from all relevant growing regions in Germany.

In the second study, a sample of orchards for which insurance data were available was used as a database. The ten-year period insurance data set contained information on the geographical location of the orchard, the annual premium rate for each orchard and the assessed loss ratio in years with hail losses. In order to calculate the expected utility model, further input factors were required. For yield data, a time series of corresponding regional apple yield data (2005-14) provided by the Federal Statistical Office was used. For the price data, a time series of marketing channel-specific nominal apple prices (2005-14) provided by the Agricultural Market Information Company was used. Key operating figures of German fruit farms (average size, subsidies per hectare, financial situation of the farm, share of rented land) were provided by the Federal Statistical Office. Production costs were calculated using the Association for Technology and Structures in Agriculture (KTBL) net return calculator for apple production.

The database of the third study comprised marketing channel-specific time series (2006-14) of weekly nominal producer prices for tomatoes, onions, apples and strawberries, provided by the Agricultural Market Information Company (AMI).

Depending on the research questions of each individual study, quantitative or semi-quantitative approaches were used. In the following sub-sections, the data (see **Table 3**) as well as the applied methods are described.

In order to capture the entire risk management process of fruit farms, an online survey with German fruit producers was conducted in 2014 (**study 1**). Overall, 105 questionnaires were used for further analysis. The survey comprised five parts, relating to (1) respondents' risk attitude, (2) the assessment of risk categories and risk sources, (3) risk management instruments applied, (4) satisfaction with the instruments applied and (5) demographic characteristics. For parts 2-4, a framework for small and medium-sized non-agricultural enterprises provided by Barodte et al. (2008) was adapted to the specific situation of fruit farms. Within this framework, risk categories were assessed according to their extent of damage and likelihood of occurrence, and single risk sources according to their importance for the farms. In contrast to many other studies in the agricultural economics risk management literature, farmers were asked which instruments they actually apply and not which they intend to apply. In order to assess the efficiency of the instruments applied, farmers were asked how satisfied they are with the applied instruments. Similar to Ewald et al. (2012), risk attitude was measured with two methods, namely self-assessment and business-related statements. Finally, the ratings of single risk sources, the use of risk management instruments and the satisfaction with applied instruments were analyzed. All calculations were conducted using IBM SPSS (version 23) for Windows.

Table 3. Overview of the data and methods applied

	Study 1	**Study 2**	**Study 3**
Data	Empirical	Secondary	Secondary
Approach	Semi-quantitative	Quantitative	Quantitative
Sample	Survey data from 105 fruit producers	Ten-year time series of 105 apple orchards insurance data, official statistics on farm parameter, prices and yields	Nine-year time series of producer prices for different crops and marketing channels
Method	Data analysis, Kruskal-Wallis-Test	Expected utility approach	Producer price volatility
Location	Germany	Germany (Bavaria)	Germany

The comparison of anti-hail nets and hail insurance in the second study (**study 2**) was conducted using an expected utility approach. The expected utility approach is a method to evaluate different options considering risk and risk attitude. For the risk-neutral decision-maker, the option with the highest expected utility will always be the optimal strategy to manage risk. In order to show the effect of risk attitude, the certainty equivalent (inverse function of the expected utility function) was calculated, as the safe amount that provides the same benefit to a risk-averse decision-maker as an risky alternative with a particular expected value and a particular variance. The difference between certainty equivalent and expected value is called the risk premium. Therefore, the difference can be understood as the willingness to pay for a risk management instrument (Mußhoff and Hirschauer, 2016).

In the third study (**study 3**), the producer price volatility for different crops and marketing channels was investigated. First, the time series of producer prices were tested with an Augmented Diggy Fuller test for stationarity. After this test, the producer price volatility was calculated. In order to analyze whether the producer price volatility for different fruits and vegetables varied to a statistically significant extent, a Levene`s test was used. Subsequently, trends of producer price volatility were analyzed. Therefore, the time series were divided into sub-time series. The producer price volatilities of each sub-time series were compared with each other with a Levene`s test for significant differences.

The individual studies can be classified along the risk management process (see **Figure 3**). The first study captures the entire risk management process. Due to the high data requirements capturing the entire risk management process, a semi-quantitative approach was used to answer the objectives of the study. In the second and third study, the relevant risk has already been identified (first step of the risk management process) and the measures for risk management are known (second step of the risk management process). The studies focus on the third step of the risk management process, namely the evaluation of the instruments applied. The overall aim can be achieved by comparing the results of the individual studies.

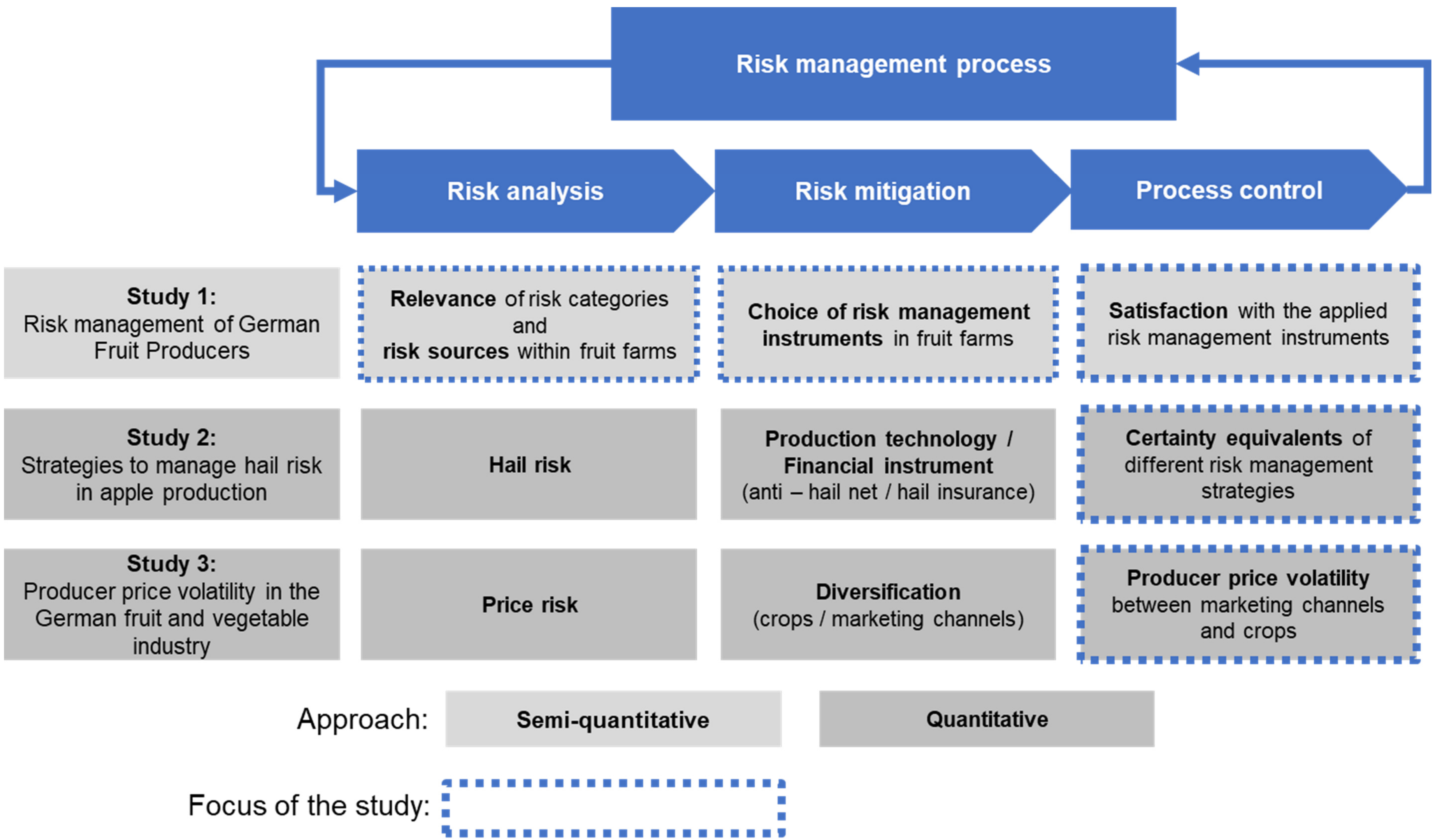


Figure 3. Structure of the dissertation

2 Risk management of German fruit producers

2.1 Summary of the study

The first presented study "Risk management of German fruit producers" described the analysis of the entire risk management process of German small and medium-sized fruit farms. The aim of the study was to develop a framework to evaluate important risks and the use of risk management instruments in German fruit production. This framework can help family-run farms to implement a risk management process on their farm and provide insights into the risk attitudes, risk perception and the choice of risk management instruments of German fruit farms. The assessment of risk sources within this framework is based on subjective probabilities. The use of this framework as well as the measurement by using subjective probabilities addresses the special needs of family-run businesses in terms of risk management that arise, e.g. from short time resources and low data availability. In order to elicit risk attitudes, two different methods were used. In the method of business-related statements, farmers were asked to choose the statement with which they most closely agree from several pre-defined statements. In the self-assessment method, participants were asked how willing they were to take risks themselves.

An online survey was conducted to comprehensively investigate the risk perception and risk behavior of German fruit producers. The survey included 105 German fruit farmers and thus 2% of the population of German fruit farmers. The average farm size amounted to 50 hectares, and most farmers were full-time farmers.

The results showed a high share of risk-seeking farmers but a weak correlation across alternative risk elicitation methods. Since most studies assume risk-averse decision-makers, the result of the bipolar distribution of farmers` risk attitudes is remarkable. The assumption frequently posited in the literature that risk-averse farmers generally assess risks higher than risk-neutral or risk-seeking farmers could not be confirmed. Because risk attitude is assumed to have an influence on the risk perception and the choice of risk management instruments, it is important that risk-neutral and risk-seeking farmers are also considered when advising farm managers regarding risk management.

The most relevant risk categories for fruit farmers were price and production risk. Within the production risk category, the most important risk sources were hail and frost. Thereby, the fruit producers interviewed showed a broad conformity in view of the assessment.

In the price risk category, the most important risk sources are the growing market power of the customers and oversupply due to market liberalization. In contrast to the other risk categories,

the single risk source assessment varied considerably between the respondents, indicating that the risk sources for the price risk were farm specific.
The analysis also showed that the risk sources in the people risk category were rated even higher. A major finding of this study was that fruit producers distinguish between personal (family workers) and personnel risk (seasonal workers, employees). This is evident in the assessment of the single risks within the risk category and the risk management instruments used.
The single risk sources within the personal risk category – which were highly rated compared with the assessment of the risk category – implied that the assessment should always be carried out at the level of the risk source, since the risk is often underestimated at the level of the risk category.
Risk categories (e.g. production or price risk) were strongly correlated and loss experience plays an important role in risk assessment, indicating that research should focus on ways to consider these facts in decision models. The interaction of risks is often neglected in risk models. However, this can be one explanation for the discrepancy between risk models' recommendations and the behavior of farmers under risk in reality. For example, if there is a negative correlation between yield and price risk, the higher price due to the lower supply can partially compensate for the yield loss.
Farmers most commonly use diversification for risk mitigation. Frequently-used forms of diversification are diversification by crops, marketing channels and additional branches. Especially in terms of price risk mitigation, the use of different marketing channels plays an important role. In order to mitigate hail risk, the majority of fruit producers use hail insurance, whereas for frost mitigation frost irrigation plays an important role. In terms of managing personal risk, farmers mainly use life insurance and accident insurance to secure the family, whereas for managing personnel risk mainly early arrangements with seasonal workers and employee satisfaction are important instruments.
In order to analyze the risk management instruments applied regarding their risk-reducing efficiency, fruit producers were asked how satisfied they were with the instruments used. In general, fruit producers are satisfied with most of the applied instruments, whereby especially technological instruments (anti-hail nets, frost irrigation, bird nets, rain protection systems) and the diversification measures show high satisfaction scores. However, in some cases there is a discrepancy between the instruments used and satisfaction with them (e.g. hail insurance and anti-hail nets).
Future research should consider developing decision models considering the interaction of risks and risk management instruments, loss experience and risk-seeking attitudes. A holistic

farm risk management approach is needed that considers all major risks (including people risk) and their interaction.

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2.2 Contributions

Annkatrin Porsch developed the research idea and the study design. She performed data analysis and the writing of the first draft of the article. Markus Gandorfer improved the study with his feedback and suggestions throughout the whole process, from the research idea up to the final manuscript. Valuable input in terms of questionnaire development, structure and interpretation of the results, as well as writing style and clarity have been contributed by Vera Bitsch.

2.3 Study

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REGULAR ARTICLE

RISK MANAGEMENT OF GERMAN FRUIT PRODUCERS

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ABSTRACT

Horticultural farms in Germany face substantial business risks. However, fruit farms often struggle to implement appropriate risk management processes, and the risk management literature widely has ignored this farm type. The aim of the study was to improve the assessment of risks by farmers and the choice of suitable risk management instruments. Therefore, a risk management process based on subjective probabilities and suitable for small and medium-sized farms was developed, considering the specific needs of family run businesses. An online survey was conducted to achieve a comprehensive view of the risk perception and risk management practices of German fruit producers. Price and production risks are the most relevant risk categories for fruit farmers. However, among single risk sources, those in the people risk category were seen as the most important. Results show significant interactions among risk categories and a significant correlation between loss experience and the rating of risk categories. The assumption that risk averse farmers generally rate risks higher than risk neutral or risk seeking farmers cannot be confirmed. Diversification seems to be the most important risk management instrument for many fruit producers, especially diversification of marketing channels, farm income, and production activities. Further research should focus on the apparent inconsistency between the satisfaction with instruments reported by farmers and the actual implementation of many of them (e.g., hail insurance and anti-hail net). Furthermore, there is a need for research, to develop decision models considering the interactions of risks and risk management instruments, loss experience and risk seeking attitudes.

Keywords: horticulture, people risk, risk management instruments, subjective probabilities
JEL: D81, Q12, Q14

INTRODUCTION

Horticultural farms face substantial challenges regarding business risks. The approval of the minimum wage in Germany, low producer prices due to the Russian import ban, yield losses due to weather extremes and food scandals have increased the need for an appropriate risk management. However, only few prior studies investigate risk management of horticultural farms (e.g., **Martin 1996; Röhrig and Hardeweg 2014; Vassalos and Li 2016**). Because substantial differences between horticultural (e.g., fruit, vegetables) and agricultural farms (e.g., cash crop, dairy) exist (Table 1), the findings of the existing agricultural risk management literature are often not transferable to horticultural farms. Additionally, most fruits are perennial crops, implying that the decision to plant a perennial crop is comparable to a long-term investment decision. Thus, in contrast to vegetable and cash crop farms, the flexibility is limited.

Table 1. Average key operating figures relevant for risk management of different full-time farm types in Germany (three-year-average; 2012/2013 to 2014/2015) (**BMELV, 2016a, b, c**)

Farm type	Total cost €/farm	Share of labour expenses on total cost %	Share of subsidies on profit %
Fruit	208.500	23	20
Vegetable	367.877	25	8
Cash crop	284.298	7	63
Dairy	220.959	3	68

Although there is no doubt that farm management needs an appropriate risk management process, the implementation remains a challenge for many horticultural farms, who are typically small and medium sized family run businesses, in contrast to larger farms with more resources to implement a risk management process (**Reynolds-Allie, Fields, and Rainey 2013**).

The agricultural risk management literature provides different approaches for analysing risks and the choice of risk management instruments. These methods can be assigned to two fields: approaches with objective probabilities and approaches with subjective probabilities (**Barodte 2008; Hardaker and Lien 2010**). The risk management literature in agriculture mostly focuses on economic decision models, and therefore, on approaches with objective probabilities. According to **Hardaker and Lien (2005, p. 3)**, the "expected utility theory has been widely, if not universally, adopted as the best basis, at least for prescriptive decision analysis". Expected utility theory is commonly used for investigating particular research questions in the context of risk management decisions, such as the use of insurance, commodity marketing, or storage. However, farmers' actual decisions are often not consistent with results of decision models (**Hardaker and Lien 2010**; **Shaw and Woodward 2008**). In addition, **Just (2003)** and **Hardaker and Lien (2010)** criticized the research bias towards short run production decisions, instead of long term or larger risks. One of the main reasons for neglecting long term or larger risks is the lack of data (**Just 2003; van Winsen et al. 2013**) to derive objective probabilities for these risks. Thus, a possible solution is to use subjective probabilities. These approaches focus on risk perception and the analysis of risk behaviour and show various advantages compared to the approaches with objective probabilities: (1) all relevant risks and potential risk management instruments are taken into consideration, (2) they have fewer requirements for data availability, (3) and they are easier to apply and provide an overview of the risks and potential opportunities of the farm business (**Barodte 2008**).

Therefore, the first objective of the study was to develop a framework to capture the entire risk management process of small- and medium-size family run fruit farms - from risk perception to risk behaviour - based on subjective probabilities. The second objective of the study was to apply the framework developed to examine the risk management practices of German fruit producers. The third objective was to determine the role of risk attitude in risk perception and in the use of risk management instruments.

MATERIAL AND METHODS

Data

For data collection, an online survey was conducted. The survey consisted of five parts: questions related to, (1) risk perceptions, (2) applied risk management instruments, (3) satisfaction with applied risk management instruments, (4) risk attitudes and (5) socio-demographic data and farm characteristics. The survey was pretested to reduce ambiguities and misinterpretation. Three consultants, two fruit producers, and nine external experts were involved in the pre-test. The revised survey was sent to 16 German fruit producer associations. These associations forwarded the survey to their members in the period of October through December 2014.

Analysis of risk perception and risk behaviour of German fruit producers

To address the special needs of family run fruit farms and to provide comprehensive insights into the risk perception and risk behaviour of German fruit producers, a framework for small and medium sized non-agricultural enterprises developed by **Barodte, Montagne, and Bouttelier (2008)** is adapted in this study (Part 1 through 3 in the survey). They proposed a four-step procedure (Table 2), which is conducted in workshops with employees. In total, they tested the framework on 34 Swiss enterprises. The present study follows the general structure of the framework suggested. However, targeted changes were introduced (Table 2), because German fruit farms are typically family run businesses, and the decision-maker is normally the farm owner solely. Qualified employees to discuss farm risk management are often not available. Therefore, group discussions did not seem suitable for this study, and were replaced by surveying farm managers.

Table 2. Structure of the risk management process analysed, and adaptations introduced to address the specific characteristics of fruit farms

Steps in the risk management process	Proposed procedure by **Barodte, Montagne, and Bouttelier (2008)**	Adaptations in this study
(1) Identification of risk categories	Group discussion with employees to evaluate risk categories	Rating the risk categories by farm managers
(2) Identification of most relevant risk categories and risk sources	Visualizing the risk categories from step (1) into a risk matrix; group discussion with employees on the main risk sources within the risk category	Rating the risk sources for each category by farm managers
(3) Identification of appropriate risk management instruments	Group discussion with employees to identify appropriate risk management instruments to reduce relevant risk sources	Choice of the applied risk management instruments for each risk source by farm managers
(4) Evaluation of the applied instruments	Group discussion with employees to evaluate the effectiveness of the instruments applied	Rating the satisfaction of the applied risk management instruments by farm managers

In the first step (Table 2), farm managers had to assess relevant risk categories (e.g., production risk). For each risk category, a definition was given, e.g., production risks mean strong negative deviation of yield or quality parameters from the average. Respondents were asked to rate the risk category on 5-point Likert scales regarding "probability of occurrence" (1 = very unlikely; 5 = very likely), and "extent of damage" (1 = negligible; 5 = catastrophic). The resulting risk score is the product of "probability of occurrence" and "extent of damage", and can range from 1 to 25.

In the second step, respondents were asked to rate single risks, associated with the risk category (e.g., hail damage in the case of production risk). Farmers rated the risk in terms of the importance for the farm on a 5-point Likert scale (1 = not important; 5 = very important) (**Meuwissen, Huirne, and Hardaker 2001; Flaten et al. 2005**). The questions were close-ended questions, but after each risk category respondents had the possibility to enumerate further sources of risk.

In the third step, respondents were asked to identify the risk management instruments applied. Therefore, a list with possible risk management instruments within a specific risk category was presented to the respondents. In the fourth and last step, respondents rated their satisfaction with the risk management instruments applied on another 5-point Likert scale (1 = extremely unsatisfied; 5 = extremely satisfied). The results were visualized in a risk matrix to identify the most relevant risk categories.

Afterwards, an analysis of internal consistency was conducted for each risk category, to determine, if the items proposed to the farmers for each risk category were suitable and reliable (**Santos 1999**). Cronbach's alpha, which is "the most widely used measure of scale reliability" (**Peterson 1994, p. 381**), served as the indicator of reliability. Items within a category are seen as reliable, if Cronbachs's alpha value is above 0.7 (**Santos 1999**). Further, the ratings of single risk sources, the use of risk management instruments, and the satisfaction with applied instruments were analysed. For testing the significance of differences among means for more than two groups (e.g., risk averse, risk neutral, and risk seeking farmers), the Kruskal-Wallis-Test was applied. All calculations were conducted using IBM SPSS (version 23) for Windows.

Elicitation of risk attitudes

Risk attitude is considered as a crucial factor in risk perception and for the decision to apply a specific risk management instrument. Many experimental techniques have been developed to elicit risk attitudes; a detailed overview can be found in **Charness, Gneeze, and Imas (2013)**. In recent years, the Holt-and-Laury Lottery, a multiple price list experiment, has become a standard method to elicit risk attitudes. Advantages of this method include the easy interpretation of the results, and the determination of critical limits of relative and absolute risk aversion coefficients (**Ewald, Maart, and Mußhoff 2012**). Still, there are several limitations of this method. First, the Holt-and-Laury Lottery is incentive conform, making it a cost-intensive elicitation technique. Second, its integration in surveys is much more difficult than psychometric methods (**Ewald, Maart, and Mußhoff 2012**). Therefore, in studies investigating risk perception and risk behavior, psychometric methods in the form of business-related statements (**Meuwissen, Huirne, and Hardaker 2001; Koesling et al. 2004; Flaten et al. 2005**) or self-assessment (e.g., **Reynaud and Couture 2012**) are commonly used. Both forms of psychometric methods are easy to apply and less time-consuming compared to a Holt-and-Laury Lottery in survey research. While some studies found that risk attitudes vary depending on elicitation method (**Reynaud and Couture 2012**), **Ewald, Maart, and Mußhoff (2012)** compared three different methods to measure risk attitudes (Holt-and-Laury Lottery, self-assessment, and business-related statements) for German farmers and found statistical significant correlations between all methods.

In the present study, self-assessment and business-related statements are used to measure farmers' risk attitudes. In the case of business-related statements respondents can choose between three statements adapted from statements proposed by **Ewald, Maart, and Mußhoff (2012)**:

1. I am willing to spend money to reduce risks, because risks concerning my business are a threat to me. (risk averse)
2. I am not willing to spend money to reduce risks concerning my business. (risk neutral)
3. I am willing to take entrepreneurial risks consciously, if there is a chance of success. (risk seeking)

As proposed by **Ewald, Maart, and Mußhoff (2012)**, an 11-point Likert scale (0= not at all risk seeking; 10 = very risk seeking) for self-assessment, and the question proposed by the SOEP (Socioeconomic Panel) (How do you consider yourself: Are you rather a risk seeking person, or do you try to avoid risks?) (**DIW 2009, 6**) are used.

To analyse the risk attitudes, which have been measured through self-assessment and to compare them to the risk attitudes, which have been measured through business-related statements, the Likert scale was condensed into three groups. The risk averse group includes respondents assessing themselves 0 through 4, the risk neutral group includes respondents selecting with 5, and the risk seeking group includes respondents, assessing themselves 6 through 10 (**Ewald, Maart, and Mußhoff 2012**).

RESULTS AND DISCUSSIONS

The study's results are based on the fully completed questionnaires of German fruit farmers. In total, 263 questionnaires have been registered in the online survey system. The length of the questionnaire resulted in a high dropout rate. For the analysis 105 questionnaires remained, due to the requirements of complete risk assessment and socio-demographic questions. The average time needed to complete the survey was 37 minutes. The desirability of a larger dataset in terms of statistical analysis notwithstanding, the sample includes

2% of the population of German fruit farmers (Table 3) and provides representative insights in the risk perception and the use of risk management instruments of German fruit farmers.

Fruit producers' risk perception

The first step of the applied risk management framework consisted of the subjective assessment of risk categories by the respondents. Results are illustrated in a risk matrix, which serves to identify relevant risks with a high damage potential, and/or a high probability of occurrence. According to the risk matrix (Figure 1), production and price risk are the most important risks, while asset risk appears least important.

Table 3. Description of the sample (n=105)

	Description	Frequency %	Mean
Age	Years		49.0
Gender	Male	85.7	
	Female	14.3	
Education	Journeyman	3.8	
	Foreman	49.5	
	Technician	4.8	
	Engineer	24.8	
	Student	5.7	
	Others	11.4	
Farm size (ha)			51.7
	<30	54.3	
	30 to 60	26.7	
	<60	19.0	
Share of rented land (%)			50.2
	0 to 50	51.4	
	>50	48.6	
Number of different fruit crops grown on the farm			2.7
	<2	21.9	
	2 to 4	65.7	
	>4	12.4	
Degree of diversification Number of horticultural or agricultural branches (not fruits)			2.1
	0	6.7	
	1	28.6	
	2	33.3	
	3	19.0	
	>3	12.4	
Number of marketing channels			2.6
	<2	27.7	
	2 to 4	59.0	
	>4	13.3	
Production system	Conventional	18.1	
	Organic	10.5	
	Integrated	71.4	
Farm financial assessment	Very positive	5.7	
	Mainly positive	43.8	
	Rather positive	41.9	
	Rather negative	6.7	
	Mainly negative	1.9	
	Very negative	0.0	
Financing farm investments (above 30.000 €)	Equity capital	52.4	
	Borrowed capital	43.8	
	No investments	3.8	
Family employees (including farm operator)			1.8
Non-family employees (without seasonal workers)			3.2

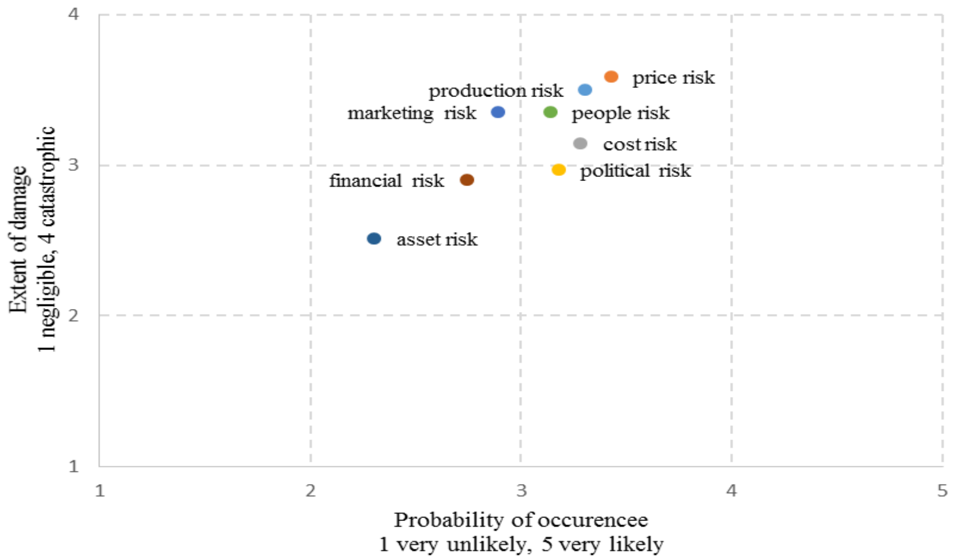

Figure 1. Risk matrix of German fruit famers

Various authors have studied farmers' perceptions of risks and risk management strategies (e.g., **Meuwissen, Huirne, and Hardaker 2001; Hall et al. 2003; Koesling et al. 2004; Flaten et al. 2005; Lien et al. 2006; Bergfjord 2009; van Winsen et al. 2013; van Winsen et al. 2014**). In these studies, price and production risk are among the highest scoring risks. Furthermore, many studies agree that political risk, i.e., changes in regulations related to farms, are important for farming. The analysis of correlations between the mean risk scores of risk categories shows significant interactions in many cases (Table 4). Interactions between risk categories were mentioned as causing inconsistency in prior studies (**Girdžiūtė 2012; van Winsen et al. 2013**). In decision models, interactions of risks can hardly be considered due to the trade-off between the complexity of the decision model and a valid description of reality.

Further correlation analysis shows that loss experience within a risk category is significantly correlated with the mean risk score of each risk category, except in the case of asset risk (Table 5). The influence of loss experience is also discussed in some recently published studies (e.g., **Menapace, Colson, and Raffaeli 2013; Hamilton-Webb et al. 2017**), concluding that farmers with loss experience are more concerned about the specific risk source compared to farmers without this first-hand experience. Therefore, recent loss experience can cause bias in the subjective assessment of risks.

Risk perception of single risk sources

The next step of the analysis was to identify relevant single risks for each risk category (Table 6). Following **Meuwissen, Huirne, and Hardaker (2001)**, risk sources rated with a risk score higher than 3.0 are relevant. In terms of production risk, frost (risk score 4.2), hail (risk score 4.0), animal pests (risk score 3.9), and plant diseases (risk score 3.6) are the most important single risks. All risk scores of single risks have standard deviations around 1.0 or less, implying a high level of consensus among fruit farmers. Cronbach's alpha for the production risk category is 0.729 and, therefore, the items are considered reliable. Frost, hail, and plant diseases can be also found in **Menapace, Colson, and Raffaeli (2012)** as relevant sources of production risk in fruit farming. Also, **Martin (1996)**, examining risk perception and risk management of eight farm types in New Zealand, stated that production risks caused by pests and diseases were very important to fruit growers.
Fruit farmers considered the growing market power of the customers (risk score 3.4), oversupply due to market liberalization (risk score 3.1), and low prices due to changing consumer preferences (risk score 3.1) as important risk sources in the price risk category. Cronbach's alpha for the price risk category is 0.821, indicating high reliability of single items. This finding is in line with **Martin's (1996)** finding that farm operators considered market risk as very important; and that changes in producer prices were of particular concern for fruit and vegetable growers.

The assessment of single risks belonging to each risk category can differ from the risk assessment of the category. For example, in the people risk category single risks within this category are rated highly, whereas the category itself seems to play only a moderate role (Figure 1). In particular, disability of the farm owner (risk score 4.7), long-term illness of the farm owner (risk score 4.7), disability of an important family employee (risk score 4.0), and long-term illness of an important family employee (risk score 4.0). With the exception of quitting of an important non-family employee (risk score 3.4), all other single risk sources in the people risk category score above 3.5. The high impact of people risk sources is in line with prior studies. Most studies agree that personal risks (e.g., death, disability, or illness of farm operator) play an important role (**Martin 1996; Meuwissen, Huirne, and Hardaker 2001; Koesling et al. 2004; Flaten et al. 2005; Lien et al. 2006**). Personal risks rank among the top 30% of all risk sources in these prior studies. Cronbach's Alpha is low for the items in this category, with a value of 0.593.

Table 4. Spearman's rho correlation coefficients of mean risk scores for risk categories (n=105)

	Production risk	Price risk	Cost risk	Political risk	Marketing risk	People risk	Asset risk	Financial risk
Production risk	1	0.331*	0.131	-0.278**	0.244*	0.240*	0.016	0.023
Price risk		1	0.337*	0.060	0.313**	0.024	-	0.128
Cost risk			1	0.191	0.107	0.205*	0.072	0.201*
Political risk				1	0.111	-0.197*	0.149	0.073
Marketing risk					1	0.016	0.141	0.124
People risk						1	0.151	0.257**
Asset risk							1	0.454**
Financial risk								1

Note: *, ** implies p <0.05 and p < 0.01 respectively

Table 5. Spearman's rho correlation coefficients[1] of mean risk scores and loss experience for risk categories (n=105)

Risk category	Spearman's rho
Production risk	.317**
Price risk	.577**
Cost risk	.301**
Political risk	.522**
Marketing risk	.263**
People risk	.364**
Asset risk	.095
Financial risk	.379**

Note: ** implies p < 0.01

Separating the single risk sources into risk sources stemming from the farm family (personal risk), and risk sources stemming from non-family employees (personnel risk) leads to an increase of Cronbach's Alpha to 0.754 and 0.663, respectively. This implies that farm owners distinguish in the risk assessment between personal risk and personnel risk.

Within the cost risk category, increasing input costs are perceived as important (risk score 3.8). The low Cronbach's alpha (0.596) for this category can be explained by analyzing the answers to the open-ended questions after each risk category. As further important risk source 21 respondents mentioned increasing personnel costs within the cost risk category. In addition, in 2014, when the survey was conducted, minimum wage legislation, including seasonal workers, was passed in Germany. In the political risk category, changing political conditions (risk score 4.1), and the macroeconomic development (risk score 3.6) are perceived as important. As expected, potential reduction of subsidies has the lowest rating (risk score 2.2), since direct payments have only a 28% share in farm profits (Table 1). Sources of marketing risk (Cronbach's alpha 0.687) are mainly marketing difficulties due to pesticide residues (risk score 3.5), and difficulties in sales due to food scandals (risk score 3.5). Sales difficulties due to low quality (risk score 3.5) is an important issue because producer prices strongly depend on fruit quality. Within the category financial risk (Cronbach's alpha 0.687), only high profit variability was rated as relevant (risk score 3.6). Reasons for high profit variability in recent years were low yields due to alternate bearing (a year with a high apple yield is followed by a year with light yield), yield losses due to weather extremes (frost in 2011, flood in 2013), and low producer prices due to the Ukraine crisis. Further risk sources within the financial risk category seem to be less relevant, which can be explained by the stable financial situation of the farms (Table 3). As expected, fire is the most important risk source in the category asset risk.

Risk management instruments and farmers' satisfaction with the instruments applied

In contrast to comparable studies, respondents were asked which risk management instruments they actually use, instead of asking for risk management instruments they perceive as relevant. To manage price risk, mainly direct farm marketing is used by 82% of respondents, and 69% sell their products through diversified marketing channels (Table 7). With a satisfaction score of 3.7 in the case of direct marketing (3.6 for diversified marketing channels), farmers seem satisfied with the effectiveness of these instruments. Further, the low standard deviation of satisfaction scores indicates a high consensus among farmers' assessments. Other instruments for price risk reduction are storage, extension of the harvest season, and processing the fruits for juice or jam. Processing has the advantage that fruits with lower quality can also be used. For example, in juice production the quality requirements are less stringent than for fresh fruits. Only 15% of all respondents manage price risk through supply contracts.

For frost risk prevention, 51% of respondents use foils and fleeces, and 45% use frost irrigation. Frost insurance is part of a multiple peril crop insurance. Only 4% of all respondents buy multiple peril crop insurance. This type of insurance plays a minor role and is not subsidized in Germany, in contrast to other countries. Therefore, insurance premiums are typically rather high in relation to the perceived benefits. To manage hail risk, many producers buy hail insurance (49%), or they opt for anti-hail nets (28%).

Table 6. Risk sources (MV = Mean Value, SD = Standard Deviation)

Single risks	Fruit farms (n=105)	
	MV	SD
Price risk		
Growing market power of the customers	3.4	1.4
Oversupply due to market liberalization	3.1	1.2
Low prices due to changing consumer preferences	3.1	1.1
Strategic misalignment of producer organization	2.7	1.6
High dependency on a single customer	2.7	1.4
Production risk		
Frost	4.2	0.9
Hail	4.0	1.1
Pests	3.9	0.9
Diseases	3.6	0.9
Storm	2.9	1.0
Drought	2.9	1.1
Heavy rain	2.8	1.2
Perishability in storage	2.6	1.3
Deer damages	2.5	1.0
People risk		
Disability of the farm owner	4.7	0.7
Long term illness of farm owner	4.7	0.5
Disability of an important family employee	4.0	1.2
Long term illness of an important family employee	4.0	1.3
Disability of an important non-family employee	3.7	1.1
Insufficient quality of work	3.6	1.0
Seasonal worker shortage	3.6	1.2
Quitting of an important non-family employee	3.4	1.2
Cost risk		
Increasing input costs	3.8	1.0
Increasing capital costs	2.9	1.2
Increasing land rents	2.7	1.3
Political risk		
Changes of political conditions	4.1	0.9
Macroeconomic situation	3.6	0.9
Increasing market liberalization	2.6	1.3
Bio-energy subsidies	2.3	1.3
Reduction of state support	2.2	1.1
Reduction of direct payments	2.2	1.0
Marketing risk		
Pesticide residues	3.5	1.3
Sales difficulties due to food scandals	3.5	1.4
Insolvency of a customer	3.3	1.4
Sales difficulties due to low quality	3.1	1.2
Financial risk		
High profit variability	3.6	1.1
High debt-services	2.9	1.4
Restricted access to loans	2.7	1.4
Low equity ratio	2.7	1.3
Asset risk		
Fire	3.7	1.1
Loss of data	3.0	1.3
Theft	3.0	1.0
Machinery breakdown	3.0	1.0
Vandalism	2.8	1.2

Table 7. Applied risk management instruments and associated satisfaction (MV = Mean Value, SD = Standard Deviation)

Risk management instrument	Fruit farms (n=105)		
	Usage	Satisfaction score	
	%	MV	SD
Price risk			
Direct farm marketing	81.9	3.7	0.8
Diversified marketing channels	68.6	3.6	0.6
Storage	58.1	3.3	0.6
Extension of harvest period	49.5	3.4	0.8
Fruit processing	48.6	3.4	0.7
Supply contracts	15.2	3.1	0.8
Production risk			
Foils or fleeces	48.6	3.5	0.7
Hail insurance	48.6	2.7	0.9
Frost protection sprinkler irrigation	42.9	3.8	0.7
Resistant varieties	42.9	3.0	0.6
Prophylactic crop protection	41.9	2.8	0.8
Rain protection system	30.5	3.6	0.8
Anti-hail nets	27.6	3.7	0.8
Bird nets	27.6	3.5	0.6
Weather derivatives	5.7	-	-
Multiple peril insurance	3.8	-	-
Wind machines	1.9	-	-
People risk			
Early consultation with seasonal workers	81.0	3.5	0.7
Disability insurance	78.1	-	-
Accident insurance	78.1	-	-
Focus on employee satisfaction	73.3	3.5	0.7
Life insurance	72.4	-	-
Mechanization	63.8	3.2	0.6
Documentation of working processes	49.5	3.0	0.7
Cost risk			
Early ordering	63.8	3.1	0.6
Buying groups	36.2	3.1	0.6
Invitation to tender	26.7	3.1	0.5
Claim default insurance	2.9	-	-
Financial risk			
Low debt service	70.5	3.3	0.9
Financial reserves	66.7	3.1	0.8
Short-term loans	38.1	2.9	0.9
Consulting with my house bank	30.5	3.0	0.9
Asset risk			
Fire insurance	92.4	3.2	0.6
Building measures (e.g., fire protection)	64.8	3.2	0.5
Machinery breakdown insurance	15.2	3.3	0.9
Business interruption insurance	11.4	3.3	1.1
General			
Diversification by branches	75.2	3.6	0.8
Use of state extension services	75.2	3.5	0.8
Spatial diversification	51.4	3.3	0.7
Use of quality management programs	42.9	2.8	0.8
Income diversification	38.1	3.4	0.8
Off-farm investments	35.2	3.2	0.6

Although more producers use hail insurance compared to anti-hail nets, results indicate that producers' satisfaction with anti-hail nets is higher (satisfaction score 3.7) than with hail insurance (satisfaction score 2.6). An explanation for the higher satisfaction score of anti-hail nets may be that hail insurance only covers the direct monetary losses from damaged fruits. The long-term consequences of an extreme hail event (e.g., loss of customer relationships) are not covered by hail insurance. Furthermore, anti-hails nets have additional positive phytosanitary effects. It is notable that 16% of the farmers use anti-hail nets and, additionally, buy hail insurance. One explanation for the combination of both instruments originates from the diversification of marketing channels. Anti-hail nets can help prevent yield and quality losses caused by hail. Consequential damages, e.g., loss of customer relationships due to the inability to fill orders, are avoided by preventing damages.

Although the people risk category seems not very important for fruit farmers (Figure 1), all single risks listed within the risk category are rated high (Table 6). The high relevance of single risk sources within the people risk category is further demonstrated by the fact that five out of the eight listed instruments to manage people risk are used by more than 70% of respondents. Particularly, different kinds of insurance, such as disability insurance, accident insurance or life insurance, play an important role to reduce personal risk. For personnel risk management, the early consultation with seasonal workers and the focus on employee satisfaction are important risk management tools. The establishment of financial reserves, as well as low debt service, are the instruments applied most commonly to manage financial risk (see also **Martin, 1996**). For reducing cost risk the common risk management instrument seems to be the early ordering. To manage asset risk, 92% of respondents purchased fire insurance.

In general, diversification is a common risk management strategy among fruit farmers. Most respondents (75%) are active in at least one other agricultural activity beyond fruits. The satisfaction scores with different diversification activities are high. Other forms of diversification applied by farmers are spatial diversification (51%), and the diversification of income sources (38%). The high relevance of diversification corresponds to other studies in agriculture (**Martin 1996; Meuwissen, Huirne, and Hardaker 2001; Koesling et al. 2004; Flaten et al. 2005; Lien et al. 2006**). Furthermore, diversification could be the reason why supply contracts and multiple peril crop insurances are used by few respondents. Several studies found that the degree of diversification had a negative influence on implementing single risk management tools, because farm income is stabilized sufficiently through different sources of income (**Finger and Lehmann 2012; Foudi and Erdlenbruch 2012**). Although 43% of respondents take part in a quality management program, satisfaction with this instrument is comparatively low (satisfaction score 2.7). A reason for lower satisfaction was identified by **Soon and Baines (2012, p. 400)**, where referring to quality management programs farmers criticized that they were "inundated with various types of paper or electronic-based risk assessments which at times were fragmented".

Fruit producers' risk attitudes

German fruit farmers, on average, appear to be risk neutral (mean value of self-assessment: 5.7; mean value of business-related statements: 2.1). However, the results of the risk attitude measurements indicate a bipolar distribution (Table 8). In both risk measurement instruments applied, most farmers described themselves as risk seeking (self-assessment 60%, business related statements 56%). Only 31% of respondents describe themselves as risk averse based on self-assessment (38% for business related statements). This result corresponds with findings by **Röhrig and Hardeweg (2014)** of a high share of risk seeking respondents (48%) among German fruit farmers based on a Holt-and-Laury Lottery. An explanation for the high share of risk seeking farmers may be that most fruit farmers described the farm financial situation as positive (Table 3).

Table 8. Response behaviour to risk attitude (n=105)

	Self-assessment (0-4 = risk averse, 5 = risk neutral, 6-10 = risk seeking)	Business-related statements (1 = risk averse, 2 = risk neutral, 3 = risk seeking)
Average value	5.7	2.1
Risk averse (%)	31.4	38.1
Risk neutral (%)	8.6	5.7
Risk seeking (%)	60.0	56.2

Ewald, Maart, and Mußhoff (2012) also found a bipolar distribution of risk attitudes and a majority of risk seeking farmers, when risk attitudes were measured based on self-assessment. However, when using business-related statements, they found a higher share of risk averse farmers (**Ewald, Maart, and Mußhoff 2012**). In the present study, only half of the participants (52%) answered the questions of both instruments to measure risk attitude consistently. Consequently, correlation analysis shows a weak, albeit significant, relationship between self-assessment and business-related statements (Spearman's rho 0.177; $p<0.05$). The significant correlation of both risk elicitation methods corresponds with the findings of **Ewald, Maart, and Mußhoff (2012)**. A possible explanation for the low correlation may be the different contexts of both risk attitude elicitation methods (**Reynaud and Couture 2012**). The low correlation of both methods to measure risk attitudes indicates that no conclusion can be drawn as to which method is most appropriate for elucidating risk attitudes.
Both, risk perception and risk attitude are expected to be relevant factors for the choice of risk management instruments (**van Winsen et al. 2014**). Therefore, in an additional analysis, the total sample was split according to the risk attitudes of respondents. Thus, the three groups (risk averse, risk neutral and risk seeking farmers) were compared according to their assessment of single risk scores. A separate analysis was conducted for each of the two methods to measure farmers' risk attitudes applied. If risk attitude is measured through the self-assessment method the only statistically significant difference relates to growing market power of the customer; this single risk source is rated higher by risk averse farmers. If risk attitude is measured through the business related statement the single risk sources drought, long term illness of an important family

employee, and pesticide residues are statistically significant. In case of drought and long term illness of an important family employee risk neutral farmers rated these risk sources higher, whereas pesticide residues were assessed higher by risk seeking farmers.

Therefore, the results presented in this study do not support the conclusions of other studies (e.g., **Meuwissen et al. 2001**) that risk averse farmers generally rate single risk sources higher than risk neutral or risk seeking farmers. Furthermore, no significant differences between the three groups (risk averse, risk neutral and risk seeking) were identified regarding the use of risk management instruments. This result corroborates **Vassalos and Li (2016**) who examined the effect of risk perception and risk attitude on the choice of marketing contracts of vegetable growers. They found that neither risk perception nor risk attitude had an impact on growers' choice of marketing contracts.

CONCLUSION

The present study provides insights into the risk perception and use of risk management instruments of German fruit farmers, using a risk management framework based on subjective probabilities. Furthermore, the role of risk attitude, which was expected to be an important factor for risk perception, and risk behaviour were analysed. Fruit farms are particularly relevant for agricultural risk management research because they represent the farm type "horticulture" and are typically family run businesses, both of which often struggle to implement risk management processes and were widely neglected in previous risk management studies.

The adopted risk management framework to analyse risk perceptions consists in two steps, the assessment of risk categories and of single risk sources within these categories. Results show that assessing risks only at the category level is not sufficient (see also **Cox 2008**). Farmers may overestimate or underestimate the risk categories (see e.g., people risk), when not considering the individual risk sources within each category. Therefore, it is crucial to identify the single risk sources. Nevertheless, the rating of risk categories by risk matrices is also valuable in terms of prioritization and to identify neuralgic points threating the farm.

Although other studies found that people risk is important for farm managers, the management of this risk is widely neglected in risk management literature. Exceptions are the studies of **Bitsch and Harsh (2004)** and **Bitsch et al. (2006)**, providing insights in risk management issues regarding non-family employees. Especially in family run farms, which are highly dependent on the farm manager, it is crucial to highlight the people risk category. Thereby, a substantial finding consists in the fact, that farm managers distinguish between people risks within the family (personal risks), and the non-family workforce (personnel risks). In case of the family workforce, farm managers prefer to hedge risk by purchasing insurance. To improve personal risk management, managers need to pay more attention to the documentation of work processes. This measure enables family members to continue the farm business, if the farm manager is absent. In case of personnel risk, early arrangements with seasonal workers, and a focus on employee satisfaction are typical instruments applied to reduce risk. These findings are in line with **Bitsch and Harsh (2004, p. 743),** who emphasize that a "timely start of the hiring season [of seasonal employees]" is necessary to "avoid manager overload during peak labor needs". As good practice for employee satisfaction, **Bitsch and Harsh (2004)** mentioned the training of new employees, regular performance evaluations, occasional get-togethers and shared meals, showing interest in employees' lives, flexibility in scheduling, sharing of business information with employees, and providing bonuses. The management of non-family labour is one of the big future challenges of horticultural farms in Germany. Thus, more research is needed on personnel risks and suitable risk management instruments.

The analysis of the applied risk management instruments indicates that various forms of diversification have high relevance for fruit farms. Although specialization is important due to economies of scale, diversification is an effective risk management strategy. Further research should focus on the farm-specific assessment of the trade-offs between economies of scale due to specialization, and risk reduction due to diversification. For example, growing different kinds of fruits may reduce price risks, but increases the number of plant protection strategies required and related input costs due to small lots and additional work steps.

In most cases, farmers are satisfied with the instruments applied for risk management. When more than one instrument is available to manage a risk source, the present study shows inconsistencies between farmers' satisfaction with risk management instruments and their actual use. As this study shows, satisfaction with hail insurance is low in comparison to anti-hail nets, despite the fact that hail insurance is applied more often. Few studies (e.g., **Pennings et al. 2008; Barnham et al. 2011; Foudi and Erdlenbruch 2012**) discuss complementary and substitution effects of risk management instruments (e.g., irrigation and drought insurance). However, the effects of interactions between different risk management instruments should receive more attention among scholars.

The bipolar distribution of farmers' risk attitudes is a far-reaching finding, since most risk management literature assumes risk averse decision makers. Furthermore, the findings of this study do not confirm the common assumption in literature that risk averse farmers generally rate risk higher than risk neutral or risk seeking farmers. Therefore, it is important to also consider risk seeking attitudes, when advising farm managers regarding risk management.

Although risk management becomes more important, many fruit farmers still struggle to implement an appropriate risk management process. The presented risk management framework addresses the special needs of family farms and is based on subjective probabilities due to the often-noticed lack of sufficient farm level data to derive objective probability distributions for single risks or for risks, which cannot be quantified (e.g., people risk). Therefore, it will allow fruit producers to identify the important risks for their business, to assess the interactions between risk categories, and to evaluate the risk management instruments they already use in terms of their satisfaction with their performance.

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3 Strategies to manage hail risk in apple production

3.1 Summary of the study

Hail risk is the most important risk source for fruit producers in southern Germany. According to different meteorological studies, the frequency as well as the extent of losses will even increase in the future, especially in this region. Therefore, hail risk management is essential for successful farm management in German fruit production. Instruments for hail risk mitigation include the spatial diversification of orchards, cloud-seeding planes, anti-hail nets and hail insurance. In practice, however, only hail insurance and anti-hail net play a role in hail risk mitigation in Germany. Especially in recent years, anti-hail nets have gained increasing attention because negative impediments (e.g. delayed fruit coloring) could be reduced and subsidies are provided by the government as well as recognized producer organizations for the installation of anti-hail nets.

Because only few studies compare technological- and financial-based instruments for risk mitigation, this paper aimed to conduct a detailed risk analysis within an expected utility framework of different strategies to manage hail risk, taking into account farmers' risk aversion and farm-specific conditions. The basis for the analysis was a data set from a ten-year time series of orchard-specific hail damage and hail insurance data.

The results showed that the efficiency of anti-hail nets and hail insurance mainly depends on the yield potential and the local hail risk of the orchard. According to the local hail risk and the yield potential, orchards were categorized into four groups. The first group comprises orchards with a low local hail risk and low yield potential. For orchards belonging to this group, no hail risk mitigation is the most efficient risk management strategy. For orchards with high local hail risk and high yield potential (group 2), the use of anti-hail nets generated the highest certainty equivalents. The reason for the higher efficiency compared to hail insurance can be explained by the cost for hail risk mitigation: the installation costs for anti-hail nets per ton of apples decline with increasing yield potential and are constant independent of the local hail risk, whereas the costs for hail insurance increase with a higher yield potential and a higher local hail risk. For the third group (orchards with high local risk but low yield potential), hail insurance is most efficient. In the fourth group (orchards with low local risk but high yield potential), the most efficient risk management strategy depends on the risk attitude. For risk-neutral or slightly risk-averse decision-makers, anti-hail nets provide the highest certainty equivalents (due to the declining costs for anti-hail net per tons of apple). However, with increasing risk aversion, there is a shift towards hail insurance, which can be explained by the higher flexibility of the instrument. In years with low yields, the insured sum can be adapted to low yields and thus the costs for hail insurance decline. However, the costs for anti-hail nets are constant and cannot be adapted. Therefore, hail insurance provides higher certainty equivalents at higher levels of risk aversion in this group of orchards.

In some cases, the current subsidy programs by the government and the producer organizations for the installation of anti-hail nets lead to a decline in the competitiveness of hail insurance, although hail insurance is more efficient compared to anti-hail nets.

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3.2 Contributions

The research idea is a result of the first study, as we noticed a discrepancy between the use of hail insurance and anti-hail nets and the satisfaction with these two instruments. Annkatrin Porsch was responsible for the data acquisition. She performed all analysis within the expected utility model under the guidance of Markus Gandorfer and wrote the first draft of the article. Markus Gandorfer also contributed valuable input in terms of interpretation of results, article structure and writing style. Vera Bitsch contributed to the research with ideas, discussion and suggestions, as well as the clarity of writing.

3.3 Study

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Strategies to manage hail risk in apple production

Abstract

Purpose – Hail risk management is essential for successful farm management in German fruit production, particularly because hail events and associated losses have increased in recent years. The purpose of this paper is to conduct a detailed risk analysis comparing different strategies to manage hail risk, taking into account farmers' risk aversion and farm-specific conditions.

Design/methodology/approach – Within an expected utility framework, two different strategies for managing hail risk are compared: one belonging to the group of financial instruments (hail insurance) and the other to the group of technical instruments (anti-hail net). A unique dataset comprising a ten-year time series of orchard-specific hail damage and hail insurance data is used.

Findings – For orchards with low local hail risk and low yield potential, not using hail risk mitigation is most efficient. For orchards with high local hail risk and high yield potential, anti-hail nets provide the highest certainty equivalents. For orchards with high local risk, but low yield potential, hail insurance is most efficient. For orchards, with low local risk, but high yield potential, the certainty equivalents are higher for anti-hail net, when the farmer is risk neutral or slightly risk-averse. With increasing risk aversion, hail insurance is most efficient, which can be explained by the greater degree of the instrument's flexibility.

Originality/value – The novelty of the study lies in the direct comparison of the risk effects of anti-hail nets and hail insurance in fruit production.

Keywords: Climate change, Risk management, Expected utility, Anti-hail net, Hail insurance, Historical simulation

Article Type: Research paper

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1. Introduction

Variability in crop yield due to extreme weather events influences the profitability and risk of fruit production. In the case of apple production, frost and hail are commonly considered the most important sources of risk for yield variability. Based on expert interviews, Gömann et al. (2015) found that hail is the first ranked risk in South Germany, followed by drought and late frost (see Table 1).

Table 1. Three most important risk sources in apple production for different production areas in Germany (Gömann et al., 2015)

Rank	North Germany (Niederelbe)	South Germany (Lake Constance)
1	hail	hail
2	late frost	drought
3	flood	late frost

Due to climate change, the frequency and extent of losses due to hail have increased in Central Europe over the past three decades (Kunz et al., 2009; Mohr and Kunz, 2013). Therefore, this study focuses on hail. Hail events often cause high yield and quality losses because the quality of apples is highly sensitive to hail, and apples damaged by hail are only suitable for sale to the processing industry (e.g., apple-juice producers) after even a moderate hail event.

In Germany, fruit production is limited to a few growing areas: one-third of the entire fruit production area is located in southern Germany (in the states of Bavaria and Baden-Wurttemberg). This region has been particularly affected by rising hail risk (Kunz and Puskeiler, 2010; Mohr and Kunz, 2013). An increase in the average number of hail days per year from 5 to 33 was recorded in South-western Germany between 1986 and 2004 (Kunz et al., 2009). In regions where hail events are more frequent, they are often also more severe (Kunz and Puskeiler, 2010). In addition to production risk, specialty crop farms are highly exposed to risk due to the capital-intensive nature of production and the often high debt-to-asset ratios as a consequence of structural change (Hartwich et al., 2015).

Therefore, an appropriate risk management strategy for hail risk is crucial. Various instruments are available for hail risk mitigation, including the spatial diversification of orchards, cloud-seeding planes, anti-hail nets and hail insurance. However, in practice, only anti-hail nets and hail insurance are generally used. Hail insurance has a long tradition in Germany, where approximately 70% of the agricultural area is insured. Although there are no official statistics concerning the percentage of apple production insured, it can be assumed that insurance is widespread to manage hail risk in fruit production. Porsch et al. (2018) found that 48% of

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surveyed fruit producers in Germany use hail insurance and 27% use anti-hail nets. Anti-hail nets have only become more important in recent years (Handschack, 2013).

Beside hail protection, anti-hail nets also reduce the risk of sunburn, which could lead to yield losses as well. However, there are also problems impeding the use of anti-hail nets including, e.g., delayed fruit coloring, more time needed until maturity, smaller fruit sizes and greater efforts for treatments against pest and diseases (Iglesias and Alegre, 2006). Technological improvements in net characteristics have reduced some of the problems associated with anti-hail net use (Iglesias and Alegre, 2006). In a previous study (Gandorfer et al., 2016), notable differences have been identified between the two instruments in terms of their ability to mitigate hail risk. Anti-hail nets can help prevent yield and/or quality losses caused by hail and thus, the potential loss of the relationships to wholesale markets, food retailers or consumers due to the inability to fill orders are avoided. This is an important advantage over hail insurance, because direct marketing and marketing via wholesale play an important role for German fruit farms. German apple producers sell on average 22 percent of their production through wholesales markets and 12 percent through direct marketing (Gandorfer et al., 2017). Both marketing channels require reliable delivery to sustain customer relationships. When selling through producer organizations, shortfalls in deliveries caused by hail only play a minor role. This can be explained by the position of the farmer in the value chain. When selling through producer organizations, farmers transfer the marketing task to the producer organization. Furthermore, they do not agree a defined amount of yield with the producer organization in advance.

Hail insurance is an indemnity insurance, meaning that the coverage includes the monetary yield and quality loss as a percentage of the agreed insured amount. The agreed insured amount should reflect the expected revenue, and it must be reported to the insurance company annually. The insurance period begins on the first day of January and ends on the last day of December. At the beginning of the growing season, neither yield nor price expectations are foreseeable. Therefore, fruit producers can report the expected revenue (insured amount) until the end of May (Keller, 2010). Farmers can decide what amount of the expected revenue to cover. According to Vercammen and Pannell (2000), the optimal insurance coverage is below 100 percent due to background risk, which occurs as a result of other sources of price and yield variability that are not covered by hail insurance.

The installation of an anti-hail net is a capital-intensive and long-term investment decision and can be considered as a technology adoption that cannot be adapted to yearly expected revenues. Therefore, hail insurance provides more flexibility to the farmer compared to anti-

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hail nets. The costs for hail insurance depend on two factors, the local hail risk and the agreed insured amount. This implies that with increasing yield potential the cost for hail insurance per ton of apples increases linearly. The cost of hail insurance ranges between 4 and 11 percent of the insured amount per hectare and year, depending on the local hail risk. The costs for anti-hail nets are constant and independent of the local hail risk and the expected revenue. However, the costs for anti-hail net per ton of apples decrease with increasing yield potential of the orchard (Iglesias and Alegre, 2006). The remaining risk in the case of hail insurance is the chosen deductible, whereas in the case of anti-hail nets the remaining risk comprises the potential occurrence of damages to the anti-hail net system or the anti-hail net itself. In contrast to most EU28 countries and the USA, hail insurance in Germany is not subsidized (Bielza Diaz-Caneja et al., 2006; Gesamtverband der Deutschen Versicherungswirtschaft e.V, 2016). Although German fruit farmers are not very satisfied with hail insurance (Porsch et al., 2018) the German Farmers` Association (DBV) requests a state subsidy, especially for multiple peril crop insurance (DBV, 2017; Röhrig et al., 2018).

For anti-hail nets, farmers can receive subsidies between 15 and 50 percent of the investment (Gömann et al., 2015). The subsidy amount depends on the respective subsidy program. Within the government program ("Agrarinvestitionsförderung"), farmers can receive 15 percent of the investment. Further, recognized producer organizations provide a subsidy program for risk management and crisis management to their members, which includes a subsidy of anti-hail nets up to 50 percent of the investment (Gömann et al., 2015). The main purpose of recognized producer organizations consists in strengthening farmers` position in the value chain by pooling the produced products. The producer organizations themselves have contracts with the customers (e.g., wholesale markets or food retailers) with a concrete amount of yield explicitly stated. Therefore, they have an interest that farmers can deliver their products and offer a subsidy for anti- hail nets to their members.

Subsidy programs have led to an increase in the installation of anti-hail nets. However, only few studies provide an economic analysis of the use of anti-hail net or hail insurance to mitigate hail risk in fruit production. Furthermore, hail risk management decisions should not be based solely on the expected net returns, but should also consider uncertainties and farmers' attitudes towards risk, since anti-hail nets and hail insurance affect the variance and skewness of profits. Therefore, the expected utility approach is applied where the farmers' objective is to choose the hail risk management option that results in the highest expected utility. The advantage of this approach is that hail risk management options can be compared considering

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farmers' risk aversion, site conditions (e.g., local hail risk, yield potentials) and relevant farm characteristics.

The objective of this paper is to conduct a detailed risk analysis comparing different strategies to manage hail risk (insurance, anti-hail net) on the basis of a time series (2005-2014) of orchard-specific hail risk and hail damage data for 105 Bavarian apple orchards (Versicherungskammer Bayern, 2016). The analysis will consider differences in local hail risk and yield potential. Furthermore, the objective is to analyze the effect of risk aversion and different financial situations on the ranking of the analyzed risk management options. Finally, the study aims to offer recommendations for the optimal risk management strategy based on farm-specific conditions, e.g., the financial situation, local hail risk and yield potential.

2. Literature Review

Studies, which directly compare the risk effects of anti-hail nets and hail insurance in fruit production are rare. However, a comparable decision situation that is well studied in agricultural economics is the choice to use irrigation systems or instead to acquire drought insurance. The decision situation is comparable, as in both cases (hail insurance vs anti-hail nets and drought insurance vs irrigation) a technology (self-insurance strategy) is compared with a financial instrument (market-based strategy) in terms of its effectiveness in managing a specific weather risk.

A wide body of studies use regression analysis to analyze farmers' actual risk management behavior, e.g., factors influencing the actual choice of risk management instruments. However, studies using an expected utility approach to analyze factors influencing the optimal risk management decision are rare due to extensive data requirements, e.g., time series of site-specific yield losses. Three studies have been identified that compare irrigation and drought insurance with an expected utility approach. These studies were analyzed to identify relevant factors that may apply to the assessment of hail insurance (market-based strategy) vs anti-hail nets (self-insurance strategy). Furthermore, two recent studies analyzed different risk management strategies for specialty crops.

Barham et al. (2011) compared different combinations of irrigation and the use of crop insurance or put options for a representative cotton farm in the Texas Lower Rio Grande Valley (USA). In simulations where irrigation was required often, irrigation technology provided a higher expected utility than insurance. In the case of low need for irrigation (low local drought risk), insurance was preferred across all levels of risk aversion.

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Lin et al. (2008) compared the use of a weather derivative (rain-based index insurance) and irrigation using an expected utility model. The authors found that across all levels of risk aversion the expected utility of irrigation was higher than the expected utility of the weather derivative.

Dalton et al. (2004) analyzed the use of different irrigation systems and crop insurance (multiple peril crop insurance with different coverage levels ranging from 50 to 75% of total yield) for a potato farm in Maine (USA). In all simulations, they found that irrigation stabilized yield variability. Nevertheless, the authors only partly confirmed the risk-reducing benefits of irrigation, because in years with no need for supplemental irrigation the investment cost of the irrigation technology had a negative impact on revenue. The alternative risk-reducing strategy analyzed in the study by Dalton et al. (2004) was the use of multiple peril crop insurance. Crop insurance was found to provide the lowest expected utility, which can be explained by the high deductible (highest available coverage level is only 75% of the expected yield). Therefore, the authors concluded that “current premium subsidies and production guarantee levels are inefficient at reducing producer exposure to rainfall risk” (Dalton et al., 2004, p. 227). However, in the case of irrigation, the expected utility increased with higher levels of risk aversion.

Ho et al. (2018) examined different risk management strategies (high-tunnels, crop insurance, and weather insurance) for small and medium sized sweet cherry producers in Michigan and New York State. The authors used several criteria, e.g., expected net returns, coefficient of variation, and distribution of net returns, to compare high tunnels, crop insurance and weather insurance (frost insurance, harvest rain insurance). They found that all risk management scenarios (insurances, high tunnels) are improvements compared to the status quo (no risk management). At higher levels of revenue, high tunnels are more effective than the insurance options analyzed.

For the two main apple production areas in Germany, Röhrig et al. (2018) compared different strategies of managing weather-related risks (hail and frost). For the southern production area, which is also the focus of this study, they compared the risk management instruments anti-hail net and hail insurance. The loss ratio due to hail is assessed with the fixed value method and a contribution rate of 21 percent is assumed. They found that for all scenarios (different apple varieties and plant densities) and across all levels of risk aversion, the certainty equivalents of the hail insurance were smaller than those of the anti-hail net.

Although initial wealth plays an important role in an expected utility framework, no detailed analyses on different wealth levels were conducted in these prior studies (Dalton et al., 2004; Lin et al., 2008; Barham et al., 2011; Röhrig et al., 2018). To summarize, studies using an

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expected utility approach have revealed various factors influencing the assessment of risk management instruments: risk aversion, local risk due to weather events, the functionality of the instrument and its costs. Because each of the studies about drought risk management described above modeled a single representative farm, different yield potentials were not considered. Nevertheless, yield potential plays an important role in determining costs. With increasing yield, the cost per ton of yield decreases in the case of a technical instrument and increases in the case of a financial instrument (Gandorfer et al., 2016).

3. Data and Methods

3.1. Risk model

An expected utility framework is used to model the decision situation of whether to opt for no hail risk management, acquire hail insurance or install an anti-hail net. Within this framework, local hail risk, farmers' risk aversion and initial wealth are considered. To describe farmers' utility, we employ the following functional form:

$$U = c + dW_t^{(1-R)} \tag{1}$$

where R is relative risk aversion, W_t is total wealth, c and d are constants that do not influence the ranking of hail risk management options (O'Connell et al., 2003). The utility function implies constant relative risk aversion and decreasing absolute risk aversion. To capture a relevant range of farmers' risk attitudes, relative risk aversion coefficients ranging from R = 0 (risk-neutral) to R = 4 (very risk-averse) were analyzed (see also Anderson and Dillon, 1992, p. 55). To calculate the expected utility of a specific hail risk management option, the following equation is used:

$$E(U(W_t)) = \sum_{i=1}^{n} U(W_{in} + S + NR_i) \cdot prob(i) \tag{2}$$

where W_{in} indicates initial wealth, S are farm subsidies, NR_i are net returns of the hail risk management option in year i, *prob(i)* is the probability of year i. Each of the years i of the ten-year time series was assigned an equal probability of 0.1. Farm subsidies S are decoupled direct payments on a per hectare basis, which are provided as a part of European Union`s common agricultural policy. These subsidies are independent of initial wealth. NR_i of different hail risk management options under study are calculated by subtracting the sum of variable and fixed production costs and hail risk management costs from revenues and, if applicable, indemnity payments.

$$NR_i = (Y_i \cdot P_i + I_i - vCP_i - CHRM_i - fCP) * A \tag{3}$$

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where Y_i indicates the apple yield in year *i*, P_i is the producer price for apple in year *i*, I_i is the indemnity payment in year *i*, vCP_i are the variable production costs in year *i*, $CHRM_i$ are hail risk management cost in year *i* (i.e., annualized cost of anti-hail net; insurance premium), *fCP* are fixed production cost including land rents, and *A* is farm size. The dataset made available by the insurance company, provides no information on the individual farm sizes. Therefore, based on the statistics of the BMELV (2016), it is assumed that the average farm size is 22 hectares.

Hail insurance premiums depend on the site-specific hail risk and the agreed insured amount. Site-specific hail risk is reflected in the insurance premium rate. The premium rate of a single orchard can vary over time depending on the occurrence of hail events. The costs for hail insurance are calculated as a product of the insured amount in year *i* and the premium rate (4).

$$CHRM_{i,I} = (Y_i \cdot P_i) * PR_i \tag{4}$$

where $CHRM_{i,I}$ indicates cost for hail insurance in year *i*, Y_i is the apple yield in year *i*, P_i is the producer price for apples in year *i*, and PR_i is the premium rate.

The indemnity payment in the case of a hail event is calculated as the product of insured amount and loss ratio adjusted for the selected deductible (5). It is assumed that the insured amount is equal to the expected revenues in year *i* and therefore can be calculated as the product of yield and price.

$$I_i = (Y_i \cdot P_i) * (LR_i - D) \tag{5}$$

Where I_i indicates indemnity payment in year I, Y_i is the apple yield in year *i*, P_i is the producer price for apples in year *i*, LR_i is the loss ratio in year *i* indicating the hail damage (%) assessed by the insurance company, and D is the selected deductible (10%). The amount of the deductible is common for specialty crops in Germany and was provided by the insurance company. However, farmers can increase the deductible to reduce the insurance premium (Keller, 2010). To receive an indemnity payment, the assessed loss ratio must be more than 10 percent.

Since expected utility is modeled based on a time series of net returns that are calculated with year-specific prices and yields, the applied model accounts for both price and yield risks. To facilitate the interpretation of the modeled expected utility values, the corresponding monetary certainty equivalent values *CE* are calculated (see Martin et al. 2001):

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$$CE_R = (1 - R)E\,(U_R)^{\frac{1}{1-(R)}}\;; R \neq 1 \tag{6}$$

Finally, a utility-maximizing farmer will choose the hail risk management strategy that shows the highest certainty equivalent value. Thus, the advantage of hail risk management strategy A compared to an alternative strategy B, assuming a specific level of risk aversion, can be expressed as the difference between the *CE* values (Δ CE) of the two strategies.

3.2. Data and assumptions

The data used in this study are insurance data from 105 apple orchards located in the German state of Bavaria. For a ten-year period (2005- 2014), the dataset comprises the geographical position of the individual orchard, the premium rate for the orchard and year, and the assessed loss ratio per year, if a hail event had occurred. All other data needed as input variables for the model have been generated from official statistics. Because no farm-specific data were used, self-selection is considered negligible.

To compare the different strategies, all three scenarios (no instrument, hail insurance, anti-hail net) have been calculated for each orchard and year. The historical loss ratios of each orchard over ten years enabled the analysis of the efficiency of the three analyzed strategies to manage hail risk.

3.2.1. Yield data

Because orchard-specific yield data were not available, a time series of corresponding regional apple yield data from 2005 to 2014 were used (Destatis, 2005-2015). The aggregated yield data on county level may lead to underestimation of the yield risk, and thus to an underestimation of the potential advantages of the risk management instruments, especially in case of hail insurance. If the expected revenue decreases due to lower yields, the negative effect of the fixed costs of anti-hail net on farms' liquidity as well as the positive effect of the possibility to adapt expected revenue annually in the case of hail insurance will be underestimated. For each orchard, detailed information on the geographical location is available. According to this information, corresponding regional yields were allocated. Therefore, in the case of no hail risk mitigation and hail insurance, Y_i corresponds to the regional apple yield in year *i* adjusted for farm-specific hail damage in year *i*. For the group where an anti-hail net was installed, Y_i corresponds to regional apple yield in year *i*. In the five different regions of Bavaria, mean regional apple yields ranged between 13 and 37 t ha^{-1} (Table 2). The use of aggregate yield data is a limitation of the present study, which may lead to an underestimation of yield variability.

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Table 2. Annual regional apple yields (Source: Destatis, 2005-2015)

Year	Yield (t ha^{-1})				
	Upper Franconia	Lower Franconia	Upper Bavaria	Lower Bavaria	Swabia
2005	7	18	10	15	33
2006	13	40	12	20	26
2007	19	43	18	20	43
2008	18	44	18	37	30
2009	19	32	15	24	31
2010	13	23	10	22	26
2011	15	40	17	25	36
2012	28	31	13	29	35
2013	25	40	9	22	25
2014	30	54	9	36	38
Mean	19	37	13	25	32
STD[1]	7	11	4	7	6
CV[2] (%)	26	34	36	35	54

[1]STD = Standard deviation; [2]CV = Coefficient of variation

3.2.2. Price data

For the study, marketing channel-specific nominal apple prices were obtained from the Agricultural Market Information Company (AMI) for the period from 2005 to 2014. The marketing channel producer organizations is used, because the majority of farmers (54 percent) are selling their apples via producer organizations. The bias due to the aggregated price data is assumed to be small due to the high concentration of food retailing in Germany, indicating that there is high price pressure and low differences in prices among different producer organizations. All nominal data were converted to real prices using the producer price index deflator "consumer price index" obtained from the German Federal Statistical Office (Destatis, 2016). The apple varieties Braeburn, Gala and Jonagold are the most common varieties cultivated on German fruit farms (Destatis, 2005-2015). Therefore, an average mixed price was calculated using the producer prices for these varieties and assuming equal shares of the three varieties (Table 3). Furthermore, the assumption was made that 90% of the harvest will be of fresh apple quality and the remaining 10% will be of the quality used for processing

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(Peter et al., 2013). Moreover, it is assumed that apple prices do not rise significantly after a hail event, because in contrast to frost, which often occurs as an accumulative risk, hail leads to small-scale damages, in most cases.

Table 3. Annual real apple producer prices

Year	Fresh apple prices (€ t^{-1})			Processing apples (€ t^{-1})			Weighted average price (€ t^{-1})
	Braeburn	Gala	Jonagold	Braeburn	Gala	Jonagold	
2005	490	574	768	426	481	730	593
2006	517	522	903	421	455	848	624
2007	521	556	892	443	477	842	634
2008	576	599	1089	501	522	1029	730
2009	472	530	1068	460	459	994	663
2010	515	531	828	430	450	778	602
2011	534	657	1054	432	526	992	720
2012	588	711	477	527	605	469	584
2013	633	815	626	597	681	622	684
2014	422	706	542	402	578	542	552
Mean	527	620	825	464	523	425	638
STD	61	99	220	60	76	90	59
CV (%)	12	16	27	13	15	21	9

[1]STD = Standard deviation; [2]CV = Coefficient of variation
Source: Agricultural Market Information Company (AMI) (2015)

3.2.3. Wealth levels

To show the sensitivity of certainty equivalents to different levels of initial wealth, two different situations were considered in the analysis. The first situation uses an average German fruit farm of 22 ha size with a 50 percent share of owned land, where an initial wealth W_{in} of 35,746 € ha^{-1} is assumed. In the second situation, initial wealth (indicating a low equity cover) is set to 19,332 € ha^{-1}, representing a farm of 22 ha size with a share of rented land of 90 percent (BMELV, 2016). The second situation was analyzed to specifically show the effect of different hail management options for farms with a low risk-bearing capacity. Therefore, the difference in initial wealth comprises the lower level of land assets. Subsidies (mainly direct payments) for an average German fruit farm amount to 367 € ha^{-1} (BMELV, 2016). The initial wealth does not influence the amount of the subsidy provided for installing an anti-hail net.

3.2.4. Production costs

Variable and fixed costs for year-specific yields Y_i are calculated using the Association for Technology and Structures in Agriculture (KTBL) net return calculator for apple production (Kuratorium für Technik und Bauwesen in der Landwirtschaft, 2016). The production costs are yield-dependent, and due to the aggregated yield-level, they will be underestimated. As the cost risk is of lesser importance in apple production, this underestimation is negligible (Hartwich et al., 2015). Total production costs for the scenario “average wealth” are shown in Table 4. The production costs in the scenario “low wealth” are 6 percent higher due to the higher share of rented land.

Table 4. Annual regional total production costs (€ ha^{-1}) for the average wealth scenario

Year	Total production cost (€ ha^{-1})				
	Upper Franconia	Lower Franconia	Upper Bavaria	Lower Bavaria	Swabia
2005	5968	7097	6282	6736	8606
2006	6521	9291	6415	7227	7887
2007	7136	9620	7030	7268	9665
2008	7064	9732	7123	9030	8329
2009	7156	8481	6804	7699	8411
2010	6531	7598	6291	7464	7845
2011	6777	9343	6979	7811	8934
2012	8110	8369	6538	8200	8853
2013	7731	9373	6138	7442	7794
2014	8336	10768	6189	8938	9120
Mean	7133	8967	6578	7781	8544
STD	744	1087	374	742	613
CV (%)	10	12	6	10	7

[1]STD = Standard deviation; [2]CV = Coefficient of variation

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3.2.5. Hail protection costs

Orchard-specific premium rates provided by an insurance company were used to calculate hail insurance premiums (Versicherungskammer Bayern, 2016). The premium rate is determined by the local hail risk, a crop-specific surcharge or discount indicating crop-specific sensitivity to hail, and the insurer's margin. In Germany, three insurance companies offer hail insurance for specialty crops. All of them have committed to using a general hail statistic provided annually by the German Insurance Association (GDV) for assessing local hail risk. Therefore, premium rates reflected in this dataset are applicable all over Germany and not limited to customers of the specific insurance company providing the data set. Premium differences may exist only due to discounts. The baseline of the study's sample comprises orchards that are insured. There are no data for orchards that are not insured. However, any possible bias can be neglected, because hail risk cannot be influenced by the policyholder (Keller, 2010).

The costs for installing an anti-hail net are assumed to be 1,800 € ha^{-1} per year (Iglesias and Alegre, 2006; Dierend et al., 2009) reduced by the generally available investment subsidy of 15 percent (see Gömann et al., 2015, p. 138). The investment subsidy is assumed at 15 percent, because higher subsidies require membership in a recognized producer organization and thus are not relevant for the majority of apple producers. To maintain the anti-hail net, there are yearly operating costs, amounting up to 91.30 Euro per hectare per year (Dierend et al., 2009). These costs have been added to the fixed costs less the investment subsidy.

4. Results and Discussion

For all 105 orchards, net returns, expected utilities and corresponding certainty equivalents for the three risk management strategies (no hail risk mitigation, hail insurance and anti-hail net) and different risk aversion levels were calculated on a one-hectare level. In accordance with the yield potential, orchards were grouped into low or high yield potential groups. The mean yield of all orchards in the sample was 25.2 t ha^{-1} (Table 2). The criterion for assignment to the low yield category was a mean yield below 25 t ha^{-1}, and for the high yield category a mean yield above 25 t ha^{-1}. Second, yield potential groups are separated according to the insurance premium rate. The premium rate of hail insurance for apple production in Germany is based on local hail risk, and ranges between 0.08 and 0.40 (Versicherungskammer Bayern, 2016). Within the sample, the lowest premium rate was 0.12, the highest was 0.29, and the mean was 0.20, which corresponds to the average Bavarian hail risk (Versicherungskammer Bayern,

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2016). In the low local hail risk group, the premium rate was less than or equal to 0.20, while in the high local hail risk group the premium rate was greater than 0.20.

4.1. The effect of hail risk management on the variability of expected net returns

For groups 1 (low yield, low risk) and 3 (high yield, low risk), the mean net returns of the strategy “no instrument” were highest, whereas for group 2 (low yield, high risk) the mean net returns of the strategy hail insurance and for group 4 (high yield, high risk) the mean net returns of the strategy “anti-hail net” were highest (Table 5). With the exception of group 1, both hail insurance and anti-hail nets reduced the coefficient of variation. Comparing hail insurance and anti-hail net, the coefficient of variation is higher for all groups for the anti-hail net strategy. The reason for the lower reduction of the coefficient of variation in the case of anti-hail net lies in the costs of the instruments. These are constant for the anti-hail net, whereas the costs for hail insurance depend on the insured amount.

Table 5. Statistics of the net returns of the different groups of orchards (n=105) within this study

	G 1: low yield, low local hail risk (n=3)			**G 2: low yield, high local hail risk (n=10)**			**G 3: high yield, low local hail risk (n=37)**			**G 4: high yield, high local hail risk (n=55)**		
	No instrument	Hail insurance	Anti-hail net	No instrument	Hail insurance	Anti-hail net	No instrument	Hail insurance	Anti-hail net	No instrument	Hail insurance	Anti-hail net
Mean premium rate		0.16			0.28			0.12			0.24	
Mean loss ratio (%)	0	0	0	23	23	23	5	5	5	16	16	16
Years with hail events	0	0	0	4.2	4.2	4.2	1.4	1.4	1.4	2.8	2.8	2.8
Mean cost for the instrument (€ ha^{-1})	0	1262	1621	0	1197	1621	0	1363	1621	0	2371	1621
	low initial wealth, share of rented land 90%											
Net returns (mean in € ha^{-1})	8355	7093	6734	-153	515	466	13135	12842	12972	8627	9179	10517
Standard deviation (€ ha^{-1})	4409	4069	4409	3578	2113	2605	6384	5596	6186	6615	2851	3391
Coefficient of variation (%)	53	57	65	2335	410	559	49	44	48	77	31	32
	average initial wealth, share of rented land 50%											
Net returns (mean in € ha^{-1})	8703	7441	7082	532	1132	1089	13483	13190	13320	9646	9875	10599
Standard deviation (€ ha^{-1})	4409	4069	4409	3632	2189	2698	6384	5596	6186	6159	3758	4303
Coefficient of variation (%)	51	55	62	683	193	248	47	42	46	64	38	41

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Thus, in years where either the yield or price expectation is low, the insured amount is low and therefore the premium is also low. However, the costs for the anti-hail net do not adjust to annual yield and price expectations and – especially in years with low yields or prices – the constant costs for anti-hail net reduce net returns even further. This finding is in line with the results of Dalton et al. (2004), who concluded that constant costs may deter farmers from investing in risk-reducing technology, such as irrigation.

A higher initial wealth from a higher level of land assets (= low share of rented land) has a stabilizing effect on the coefficient of variation of net returns. A lower net return variability indicates a lower need to implement risk management measures. These results confirm the findings of studies analyzing farmers' actual risk management behavior (e.g., Finger and Lehmann, 2012; Foudi and Erdlenbruch, 2012; Chakir and Hardelin, 2014). These studies show that increasing wealth has a negative effect on the willingness to implement risk management instruments.

4.2. The effect of hail risk management strategies on certainty equivalents

Based on the calculated expected utility of the risk management strategy, the certainty equivalent was derived for various individual levels of relative risk aversion. A positive (negative) difference (∆ CE in € ha^{-1}) between two risk management strategies indicates a higher (lower) expected utility for the first-named strategy (Table 6). In general, the differences between the certainty equivalents for the choice to implement no hail risk mitigation and both hail risk mitigation strategies were lower for farms with high initial wealth than for those with lower initial wealth, for all groups.

In case of low yield potential and low local hail risk (group 1), the certainty equivalents were highest when no hail risk management was adopted. For orchards with a high yield potential and a high local risk (group 4), anti-hail net is across all levels of risk aversion and independently of initial wealth, the risk management strategy with the highest certainty equivalents. These findings correspond with findings by Röhrig et al. (2018) that in the region around Lake Constance (region with high yield potential and high local risk), hail insurance is not an appropriate alternative to anti-hail net in terms of certainty equivalents.

For orchards with a low yield potential and a high local risk (group 2), the certainty equivalents were highest when hail insurance was used. This observation can be explained by the greater flexibility of the hail insurance in terms of costs, especially in years with low revenues. Until the end of May, farmers can inform the insurance company about the expected revenue (insured

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amount) of the orchard and therefore they can adopt the insurance premium to their yield and price expectations. For group 2 (low yield, high local hail risk), the positive impact of the flexibility of hail insurance is shown through the analysis of the costs per ton of apples. In the case of hail insurance, increasing site-specific yield leads to constant costs per ton of apples because the insurance premium also increases linearly. In the case of the installation of an anti-hail net, the cost per ton of apples decreases with increasing yields.

For the orchards in group 2, the costs for anti-hail net installation per ton of apples were considerably higher than those for hail insurance due to the low yield potential. Especially in years with low revenues, this can lead to a risk-increasing effect, because the high costs for installing an anti-hail net would further reduce profits. However, the costs for hail insurance would be lower in years with low revenues due to the possibility of adapting hail insurance annually to reflect revenue expectations. These findings were not sensitive to the different levels of initial wealth.

Table 6. Differences in certainty equivalents for the net returns (€ ha^{-1}) of the different risk management strategies (no instrument, hail insurance, anti-hail net) (subsidy level = 15%)

	G 1: low yield, low local hail risk (n=3)			G 2: low yield, high local hail risk (n=10)			G 3: high yield, low local hail risk (n=37)			G 4: high yield, high local hail risk (n=55)		
Relative risk aversion (RRA)	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net
						Low wealth						
RRA = 0	-1262	-1621	359	668	619	49	-293	-163	-130	552	1889	-1338
RRA = 2	-1207	-1655	448	1075	923	151	-45	-151	106	2283	3533	-1249
RRA = 3	-1184	-1669	485	1282	1082	199	57	-184	241	3338	4544	-1206
RRA = 4	-1166	-1683	517	1488	1244	244	133	-243	376	4378	5541	-1163
						Average wealth						
RRA = 0	-1262	-1621	359	600	557	43	-293	-163	-130	220	948	-728
RRA = 2	-1220	-1634	415	808	704	104	-124	-137	13	781	1421	-640
RRA = 3	-1201	-1640	439	911	777	135	-47	-139	92	1095	1689	-594
RRA = 4	-1185	-1645	461	1013	849	164	22	-151	173	1421	1968	-547

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For orchards with a high yield potential and a high local hail risk (group 4), both hail insurance and anti-hail net showed higher certainty equivalents compared to the strategy of not adopting any hail risk mitigation. Anti-hail net was preferable to hail insurance regarding the certainty equivalents in all constellations analyzed. The costs for the instruments have a greater impact on the ranking of the different management options than risk aversion. With increasing yield, the costs for the anti-hail net per ton of apples decrease, whereas the costs for hail insurance increase. The insurance costs also increase with increasing local hail risk, whereas the costs for the anti-hail net are independent of the hail risk. This observation corresponds with Barham et al.’s (2011) conclusion that, based on the calculated certainty equivalents regarding drought risk, at lower drought risk levels farmers preferred insurance and at higher levels of drought risk irrigation technologies were considered preferable. Further empirical studies analyzing the usage of drought insurance and irrigation technology show similar results. With increasing local drought risk, the probability that a farmer will choose to either use irrigation technology or crop insurance increases (e.g., Foudi and Erdlenbruch, 2012; Chakir and Hardelin, 2014). Finger and Lehmann (2012) ascertained that with increasing local hail risk, the use of hail insurance increases.

In contrast to groups 1 (low yield potential, low local hail risk), 2 (low yield potential, high local risk) and 4 (high yield potential, high local hail risk), risk aversion has an effect on the ranking of hail risk management options for group 3 (high yield potential, low local hail risk). For group 3, the certainty equivalent of no hail risk mitigation was always higher compared to that for the use of anti-hail net across all levels of risk aversion, and up to a relative risk aversion of 1 (for low initial wealth) or 2 (average wealth) when compared to hail insurance (see Figure 1).

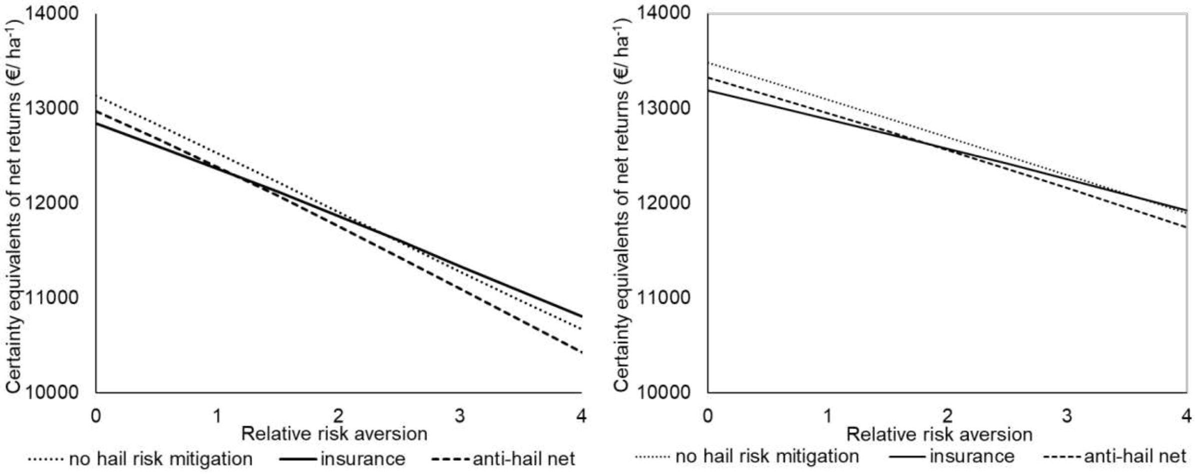

Figure 1. Certainty equivalents for group 3 (high yield potential, low local hail risk) for different initial wealth levels

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The advantage of hail insurance for this group of orchards can be explained by the costs of the instruments. Due to the heterogeneity of site-specific hail risk, there is a range of premiums per hectare for hail insurance, whereas the costs for anti-hail net are independent of the local hail risk. These findings are in line with Dalton et al. (2004), who found that fixed costs can reduce the incentive to implement irrigation technology in the case of low local drought risk. Hence, the flexibility of hail insurance in terms of costs may be an advantage for farmers who are more risk-averse or are in a tense financial situation.

Table 7. Differences in certainty equivalents for the net returns (€ ha^{-1}) of the different risk management strategies (no instrument, hail insurance, anti-hail net) (level of subsidy = 0%)

	G 1: low yield, low local hail risk (n=3)			G 2: low yield, high local hail risk (n=10)			G 3: high yield, low local hail risk (n=37)			G 4: high yield, high local hail risk (n=55)		
Relative risk aversion (RRA)	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net	I Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net
Low wealth												
RRA = 0	-1262	-1891	629	668	349	319	-293	-433	140	552	1619	-1068
RRA = 2	-1207	-1931	724	1075	650	425	-45	-433	388	2283	3260	-976
RRA = 3	-1184	-1948	763	1282	807	475	57	-473	530	3338	4270	-931
RRA = 4	-1166	-1963	798	1488	967	521	133	-538	671	4378	5266	-887
Average wealth												
RRA = 0	-1262	-1891	629	600	287	313	-293	-433	140	220	1619	-1068
RRA = 2	-1220	-1907	687	808	433	376	-124	-411	287	781	2477	-1008
RRA = 3	-1201	-1913	712	911	505	406	-47	-416	369	1095	2976	-978
RRA = 4	-1185	-1920	735	1013	576	437	22	-431	453	1421	3507	-949

This observation is supported by empirical studies analyzing the implementation of irrigation technology to manage drought risk. Ihli et al. (2012) found that risk-averse farmers tend to invest earlier in irrigation technology compared to less risk-averse farmers, but they also disinvest earlier than their less risk-averse counterparts. Viscusi et al. (2011) pointed out that an individual with higher risk aversion should make lower investment decisions.

Finally, the effect of the level of subsidy is analyzed. In the basic scenario of this study a subsidy of 15 percent is assumed. To analyze the effect of the subsidy, different levels have

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been included in the calculation. First, no subsidy of anti-hail net is assumed. As the results indicate (see Table 7), the subsidy level of 0 percent has no effect on the general ranking of the risk management strategies with exception of group 3. In this group, the results show that hail insurance dominates anti-hail nets even for risk neutral or risk averse decision makers. Second, the scenarios are calculated with a 50 percent subsidy of anti-hail net. Although there is no change in the most efficient strategy against hail risk for group 1 and 4, for orchards in groups 2 and 3, anti-hail net becomes the most efficient risk management strategy (see Table 8). Therefore, it can be concluded, that the subsidy of anti-hail net leads to a decline in the competitiveness of hail insurance in some cases.

Table 8. Differences in certainty equivalents for the net returns (€ ha^{-1}) of the different risk management strategies (no instrument, hail insurance, anti-hail net) (level of subsidy = 50%)

	G 1: low yield, low local hail risk (n=3)			G 2: low yield, high local hail risk (n=10)			G 3: high yield, low local hail risk (n=37)			G 4: high yield, high local hail risk (n=55)		
Relative risk aversion (RRA)	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net	Insurance / no instrument	Anti-hail net / no instrument	Insurance / anti-hail net
						Low wealth						
RRA = 0	-1262	-991	-271	668	1249	-581	-293	467	-760	552	2519	-1968
RRA = 2	-1207	-1011	-195	1075	1562	-487	-45	506	-551	2283	4169	-1886
RRA = 3	-1184	-1020	-165	1282	1724	-443	57	488	-432	3338	5184	-1846
RRA = 4	-1166	-1028	-138	1488	1889	-401	133	445	-312	4378	6184	-1806
						Average wealth						
RRA = 0	-1262	-991	-271	668	1249	-581	-293	467	-760	552	2519	-1968
RRA = 2	-1220	-999	-221	878	1405	-528	-124	504	-628	1470	3381	-1912
RRA = 3	-1201	-1003	-199	982	1483	-502	-47	508	-555	1999	3882	-1884
RRA = 4	-1185	-1006	-179	1085	1562	-476	22	501	-479	2558	4414	-1856

5. Conclusions

The ongoing climate change process presents major challenges for the agricultural sector. Whereas in cash crop production drought is seen as the most important risk source, hail is the most important source of risk in fruit production (Gömann et al., 2015). Studies comparing alternative strategies for managing the same weather-related risk source are rare. Therefore,

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this study aimed to compare anti-hail nets (self-insurance strategy through technology) and hail insurance (market-based strategy through a financial instrument) using an expected utility approach and further compare these results with studies analyzing a similar decision situation, namely irrigation technology versus drought insurance.

The reduction in the variability of net returns is an important reason for farmers to opt for a risk mitigating strategy. It can be concluded that the use of a technology (anti-hail net or irrigation) leads to yield stabilization, but not necessarily to stabilization of net returns. This was especially true in orchards where no hail damage occurred or in the case of drought risk, in cases where no supplemental irrigation was necessary (see Dalton et al., 2004; Barham et al., 2011). However, at higher levels of local risk, the use of a technology to reduce production risk results in lower variability of net returns than no risk mitigation.

For orchards with a low yield potential and a low local hail risk, the strategy of no hail risk management is the most risk efficient strategy. For orchards with a low yield potential and a high local hail risk, the strategy of hail insurance is the most risk efficient strategy, because the costs for hail insurance were considerably lower than those for anti-hail net due to the low yield potential. For orchards with a high local hail risk and a high yield potential, the use of technology is more appropriate because the technology entails constant costs per hectare, independent of the local risk. The dissatisfaction of the policyholders regarding the performance of the insurance strategy (Porsch et al. 2018), which is similar to the studies analyzing management of drought risk (Dalton et al., 2004; Barham et al., 2011), was confirmed by the present study in general terms. Nevertheless, a key result of this study is the finding that hail insurance is preferable to anti-hail net installation at high levels of farmers' risk aversion for the group high yield potential but low local risk. This can be explained by the higher flexibility of hail insurance in terms of annual costs. Another factor in the annual costs of hail insurance is the deductible. Due to the database, the effect of different deductibles could not be considered, because the height of the deductible is an essential risk characteristic in the hail insurance tariff. Nevertheless, this is a question that could be pursued in future studies.

However, technologies offer an essential advantage compared to insurance in terms of mitigating production risk, which cannot be considered in a risk model. Their advantage lies in preventing the potential loss of customer relationships. Especially for farms with direct marketing or selling their apples via wholesale markets or food retailers, the relationship to their customers and therefore, their ability to deliver their products is important. The potential loss of business partners due to limited ability to deliver may be also the reason for the present subsidy policy for anti-hail nets, especially by recognized producer organizations. They pool

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the farmers` products and undertake the marketing task for them. For this function, they are subsidized by the EU's common agricultural policy. Nevertheless, especially for larger fruit farms the advantages of producer organizations (e.g., joint marketing) are lower. Therefore, it is important for producer organizations to be an attractive partner for producers as well as for customers. For producers, the main functions of producer organizations include ensuring sales as well as reducing income variability (see Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, 2017). For customers, the main function provided by producer organizations is delivery reliability. This function is best served through the anti-hail nets for both producers and customers. However, subsidies of anti-hail nets lead to a decline in the competitiveness of the hail insurance, despite the advantages of insurances in some situations.

Furthermore, technologies to mitigate production risk often generate public controversy. Fruit production is frequently located in regions with high levels of tourism, where hail nets are criticized for having negative effects on the landscape. Comparable to some communities in South Tyrol (Italy), the prohibition of anti-hail nets is also discussed in some communities in Germany (Enderle, 2016). However, in most cases, the purchase of insurance is a viable alternative to anti-hail nets given that differences in the certainty equivalents between technological risk mitigation strategies and insurance are moderate in all cases, except those with high yield potential and high local risk. This public debate shows a trade-off between tourism and agriculture. Both are important employers, and both are subsidized by the government. However, apple production also forms the characteristic landscape in these tourism regions. Future research should therefore focus on alternatives for anti-hail nets in case of a prohibition of anti-hail nets and alternative types of anti-hail nets with less impact on landscapes.

If local communities decide to prohibit anti-hail nets, the government could consider an insurance subsidy for those farms belonging to the group with high yield potential and high local hail risk. If the subsidy were coupled with the local hail risk, it might still be conform to the WTO requirements.

The study does not consider the influence of apple varieties (different price and yield levels) on the ranking of risk management strategies. Nonetheless, the results offer an orientation regarding the most efficient risk management strategy depending on the yield and price level of the individual farm. Depending on the farm's marketing channels and the apple varieties planted, a combination of risk management strategies can also be the most suitable option for the farm. An example could be, using anti-hail net for apple varieties that are sold via wholesale or direct marketing and for high-price apples, and using hail insurance for apple varieties with a lower price level or apples that are sold via producer organizations. This may be an explanation for the combination of anti-hail nets and hail insurance, observed by. Porsch et al. (2018) where 16 percent of the farmers surveyed used both hail insurance and anti-hail nets. For future research, the presented results should be retested with a broader dataset, including orchards with different apple varieties, marketing channels as well as risk management strategies, to provide further insights.

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4 Producer price volatility in the German fruit and vegetable industry

4.1 Summary of the study

According to the first study (see chapter 2), price risk is the most important risk category in fruit production. Various factors are discussed in the literature to explain the increasing price risk in fruit production. Globalization and the ongoing process of concentration in food retailing lead to strong market pressure for fruit producers and low producer prices. The Russian import ban is one example of the political risk that increases producer price volatility. Food crises (e.g. E. coli) are a further reason for the rising producer price volatility. The price risk is also increased by the perishability and seasonality of many fruits and vegetables, because it is not possible to wait for a better time for marketing. At the same time, no external risk management instruments exist to reduce the price risk. While the development of price volatility for agricultural commodities has been intensively examined in recent years, there remains a research gap in the fruit and vegetable sector.

Since no external price risk management instruments exist, the diversification of marketing channels and the diversification of different crops are essentially the only strategies to reduce price risk in fruit and vegetable production. Therefore, it is important to know the producer price volatility of different marketing channels and crops to decide whether diversification could help to mitigate price risk. Thus, the aim of this study was to analyze the price risk of different fruits and vegetables as well as the price risk of selected marketing channels using volatility analysis (quantitative approach). The study analyzed the producer price volatility of apples, strawberries, tomatoes and onions in the German market. For the analysis, time series (2006-14) of weekly producer prices were used. The marketing channels under study were wholesale markets and producer organizations.

The results indicate that German fruit and vegetable producers must deal with a high producer price volatility, which also differs between marketing channels and crops. Selling through the wholesale market results in the lowest producer price volatility for all analyzed fruits and vegetables, except for strawberries, whereby apples had the lowest producer price volatility, followed by onions, tomatoes and strawberries. The producer price volatility for strawberries was lower when they were sold via producer organizations. Apples are the crop with the lowest producer price volatility when marketed via producer organizations. The order in terms of price volatility for the producer organizations is apple, tomato, strawberry and onion. Although marketing via the wholesale market showed the lowest producer price volatility, it must be considered that this marketing channel is not accessible to every fruit producer (e.g. due to the required harvest quantities). Therefore, it is important to ascertain why the price volatility of

producer organizations is higher than that of wholesale markets. The target group of producer organizations are small and medium-sized fruit farms. For these farms, producer organizations are sometimes the best alternative for selling their fruits, because due to the required harvest quantities they do not have access to other marketing channels, such as wholesale markets.
The producer price volatility of strawberries is comparatively high compared with other crops. This can be explained by the high perishability, the low storability and the short marketing period. Especially at the beginning and end of the marketing period, high prices can be achieved, although during the main marketing period the prices sharply decline. The opposite example is the apple, which is characterized by a low perishability, high storability and a large marketing period, whereby it has comparatively low price volatility.
The second research question of the study was whether producer price volatility has increased in the past nine years. With exception of apples marketed via producer organizations, there was no statistically significant evidence that the producer price volatility has been increased over recent years. Therefore, it is important to distinguish between horticulture and agricultural crops in discussions about producer price volatility.

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4.2 Contributions

First authorship is shared between Markus Gandorfer and Annkatrin Porsch. Markus Gandorfer developed the research question while working on the study “Success factors of fruit and vegetable producer organizations in the course of internationalization of the hortibusiness” (Gandorfer et al., 2016). Annkatrin Porsch was responsible for the acquisition and analysis of the data. Markus Gandorfer wrote the first draft of the article. Annkatrin Porsch and Vera Bitsch contributed to the structure and writing of the article with ideas and suggestions, as well as text editing.

4.3 Study

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Contributing research paper

Producer price volatility in the German fruit and vegetable industry

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Summary

The study analyzes producer price volatility of apples, strawberries, tomatoes, and onions on the German market. For the analysis, time series (2006–2014) of weekly producer prices were used. Marketing channels under study are wholesale markets and producer organizations. Results indicate that German fruit and vegetable producers have to deal with high producer price volatility that differs between marketing channels. Selling through the wholesale market results in the lowest producer price volatility for all analyzed fruits and vegetables, except for strawberries. Therefore, producers can partially manage their price risk by deciding on a specific marketing channel. Furthermore, the results show that contrary to popular belief, there is no clear indication of an increase in producer price volatility of fruits and vegetables in the past decade. In conclusion, developing innovative instruments to manage price risk of fresh produce remains an important task for the future.

Keywords
fresh produce, marketing channels, risk management, time trends in price volatility

Significance of this study

What is already known on this subject?
- Producers of fruits and vegetables are exposed to high price and production risks.

What are the new findings?
- Price volatility differs between marketing channels. However, there is no clear indication of an increase in price volatility in the past decade.

What is the expected impact on horticulture?
- German fruit and vegetable producers can partially manage their price risk by deciding on a specific marketing channel.

Introduction

Price volatility belongs to the most important sources of risk in fruit and vegetable production. Competitive pressure is continuously increasing due to globalization (Lange, 2009) and concentration trends in retail (Flenker et al., 2009). In addition, political risks, like Russia's ban on fruits and vegetables produced in the European Union, and food crises (e.g., *E. coli* outbreak in 2011) are discussed as possible reasons for increasing producer price volatility. Seasonality of many fruits and vegetables is further amplifying the issue. Also, perishability constrains the possibility to store fruits and vegetables, and leads to volatile markets (Cook, 2011). Furthermore, limited availability of price hedging instruments (Hartwich and Gandorfer, 2014; Hartwich et al., 2015) challenges price risk management. For instance, commodity futures contracts do not exist due to the perishability and limited storage capability of most fresh produce (see Manfredo and Libbin, 1998). The only horticultural products traded at commodity exchanges are orange juice, cacao, and coffee (www.theice.com). A commodity exchange is a market in which standardized (quantity, quality, and price) futures contracts are traded to hedge price risk (see OECD, 2009). Therefore, the choice of the marketing channel is one of the most important options available to fruit and vegetable producers to manage price risk.

Relevant marketing channels in the German fruit and vegetable industry are producer organizations, wholesale markets, direct marketing (e.g., farmers markets), and supply contracts with retailers and the food industry. The share of each marketing channel varies between fruits and vegetables. For instance, more than 50% of the apples and tomatoes produced in Germany are sold through producer organizations. On the contrary, direct marketing is the most important marketing channel for strawberries and onions (Table 1).

According to the Bavarian State Ministry for Food, Agriculture, and Forestry (2014), producer organizations should play an important role in risk mitigation by pooling production, and therefore, generating more stable producer prices through increased market power. In order to support fruit and vegetable farmers, the Common Agricultural Policy of the European Union provides subsidies for producer organizations if they fulfill specific criteria.

Although trends in price volatility have been researched extensively for agricultural commodities in recent years (Gilbert and Morgan, 2010), a lack of knowledge exists in the fruit and vegetable sector. For fruit and vegetable producers, the knowledge what price risk is associated with each specific marketing channel is paramount for related business decisions. This information is essential to develop appropriate price risk management strategies, particularly when instruments to manage price risk are limited. Therefore, the study investigates whether there are differences in producer price volatility among marketing channels in the German fruit and vegetable industry. Furthermore, the study seeks to provide insights in time trends of producer price volatility, because according to popular belief, producer price volatility has increased after recent food crises.

TABLE 1. Share of marketing channels in Germany (2012), in %.

	Apple	Strawberry	Tomato	Onion
Industry	12	1	0	9
Recognized producer organizations	54	17	56	22
Wholesale and retail	22	34	30	12
Direct marketing	12	48	14	57

Based on data provided by the Agricultural Market Information Company, 2015.

Literature review

Volatility of agricultural commodity prices is a well-researched topic that attracts growing attention in the recent scientific literature. Price volatility is one of the most important sources of risk for fruit and vegetable producers (see Hartwich et al., 2015) due to its negative effect on farm income stability. High price volatility leads also to "extremely serious risks and potential high costs for society" (Prakash 2011, p. 21). As a result, price volatility is a major concern for policy-makers and actors in the supply chain (Huchet-Bourdon, 2011). A study by Felis and Garrido (2015) emphasizes these concerns. They analyze the impact of price volatility on the market power of actors (retailer, wholesaler) in the fresh produce supply chain, and find that market power is sensitive to price volatility. Increasing price volatility caused by external shocks rises the variability of their price margins.

Gilbert and Morgan (2010) identify increases in the variance of demand and supply shocks as sources that possibly increase price volatility. Examples of recent demand shocks in the fruit and vegetable sector are Russia's import ban on European fresh produce (European Commission, 2014), and food crises, like *E. coli*. For instance, Bitsch et al. (2014) describe significant decreases in the percentage of German households buying cucumbers when the *E. coli* outbreak started in 2011. Supply shocks in the fruit and vegetable sector are mainly associated with severe weather events (e.g., frost or hail) or diseases. For a more detailed empirical analysis of variables (e.g., stocks levels, yields, exchange rate, and oil price volatility) that may affect volatility, see Balcombe (2011) and Brümmer et al. (2016).

Three research questions are of particular interest when analyzing producer price volatility: 1) Is price volatility of agricultural crops increasing over time? 2) Is there a difference in price volatility between different crops? 3) Do marketing channels differ in terms of price volatility? The vast majority of available studies (e.g., Sumner, 2009; Artavia et al., 2011; Gilbert and Morgan, 2010; Wang et al., 2010; Huchet-Bourdon, 2011) is focusing on questions 1) and 2). The main emphasis of these studies lies on cereals, meat, and dairy. Only few studies consider specialty crops, including fruits and vegetables (e.g., Gilbert and Morgan, 2010; Wang et al., 2010). According to the authors' knowledge, no recent studies compare different marketing channels for specialty crops in terms of price volatility.

Regarding the question whether price volatility of agricultural products has been increasing over time, the reviewed studies show comparable results. Gilbert and Morgan (2010, p. 3033) conclude in their review that volatility has been increasing in the last years but "the recent episode does not appear exceptional" compared to the past. Also, Huchet-Bourdon (2011) argues that volatility of agricultural product prices showed no increasing trend in the long run. Artavia et al. (2011) conclude that price volatility in Germany increased substantially for wheat, barley, and milk in the period between 1993 and 2008. Price volatility of canola and beef was only slightly increasing, and volatility of pork prices was decreasing in the same period. The authors argue that the increasing trend in price volatility in the case of wheat, barley, and milk was associated with market deregulation in the analyzed period.

Wang et al. (2010) are among the few authors that analyze price risk of fruits. They distinguish between three groups of crops regarding their market risk by applying the value at risk concept to Chinese wholesale market prices (2000–2009). Strawberries and watermelons show high market risk, grapes and oranges medium market risk, and apples, bananas, and pears low market risk. Gilbert and Morgan (2010, p. 3025) show that price volatility of fresh fruits, namely bananas and oranges, is much higher compared to other agricultural products, like grains. While price volatility of analyzed grains is between 19.2% and 23.3% (1990–2009, prices in real US dollars), the price volatility of bananas and oranges is 65.5% and 45.1%, respectively.

To summarize, there is broad consensus in literature that price volatility of agricultural commodities was high in recent years, but not exceptional taking a long-term view. Available studies show that price volatility of fresh produce is higher compared for agricultural commodities, but there is only few information available in terms of time trends and differences in price volatility of marketing channels.

Data and methods

In terms of consumption and production, tomatoes, onions, apples and strawberries belong to the most important fruits and vegetables in Germany. For the analysis, we use marketing channel specific time series (2006–2014) of weekly nominal producer prices for tomatoes, onions, apples and strawberries, provided by the Agricultural Market Information Company (AMI). Nominal prices were deflated using the food and non-alcoholic beverages consumer price index (Destatis, 2015), with the base 2010. Only data that were consistently available over the years for the marketing channels were considered in the analysis. For apples and onions, prices form calendar week 1 to 52 were used, for strawberries from calendar week 27 to 38, and for tomatoes from calendar week 12 to 52.

Price volatility is defined as "a directionless measure of the extent of the variability of a price" (Gilbert and Morgan, 2010, p. 3023). Thus, price volatility can be analyzed by various measures, including the coefficient of variation, the corrected coefficient of variation or the standard deviation of the logarithm of prices in differences (Huchet-Bourdon, 2011). As Gilbert and Morgan (2010) pointed out the analysis of price volatility should be based on detrended price data to avoid trends bias volatility measures. To avoid detrending that requires an assumption about a specific trend model, price volatility is often described by the standard deviation of price returns (Gilbert and Morgan, 2010). Price returns can be described in this context as the relative change of prices (ratio of the price at time *t* and the price at time *t*-1). Thus, based on Artavia et al. (2011), historical producer price volatility (1) is calculated in this study as the standard deviation of returns R_t.

$$\sigma = \sqrt{\frac{1}{n-1} * \sum_{t=1}^{n}(R_t - \overline{R_t})^2} \qquad (1)$$

Where R_t is the log return:

$$R_t = logY_t - logY_{t-1} = log(\frac{Y_t}{Y_{t-1}}) \qquad (2)$$

Y_t is the price at time t.

Stationarity of time series is important in order to provide unbiased comparison between market channels. To check whether time series are stationary, the augmented Dickey-Fuller (ADF) test (the null-hypothesis assumes non-stationarity) is employed (Said and Fuller, 1984).

To assess whether historical producer price volatility is increasing over time, the time series are split into two sub-periods. Data of 2006 is excluded from this analysis to be able to compare two sub-periods of equal length. Sub-period 1 lasts from 2007 to 2010 (before the *E. coli* outbreak) and sub-period 2 from 2011 to 2014 (after the *E. coli* outbreak). The time series are split into the time periods before and after the *E. coli* outbreak to analyze the impact of food crises on producer price volatility. Finally, the Levene's test is used to test for differences in historical producer price volatility between sub-period 1 and 2, and between the market channels under study. Gastwirth et al. (2009) describe the Levene's test as a powerful and a popular approach to check the homogeneity of variances. The authors provide examples where the test was successfully used in economic studies, including a study that analyzes time trends of oil price volatility. Also, Artavia et al. (2011) use the Levene's test to analyze agricultural price volatility.

Results and discussion

Descriptive statistics of weekly producer prices show that selling through wholesale markets results in generally higher prices compared to selling through producer organizations (Table 2). However, it has to be considered that mean prices are not directly comparable since selling through wholesale markets is associated with additional cost (e.g., packing).

The analysis shows that selling through the wholesale market results in the lowest producer price volatility for the analyzed fruits and vegetables, except for strawberries (see Table 3). In the case of strawberries, selling through producer organizations is associated with a marginal (not statistically significant) lower producer price volatility. This suggests that strawberries are the only case analyzed where producer organizations are successful in providing comparable price stability to the alternative marketing channel. A possible explanation for this result is that many producer

Table 2. Descriptive statistics of weekly producer prices (€ 100 kg^{-1}) for the period 2006–2014 (calculated based on data provided by AMI).

	Apple		Strawberry		Tomato		Onion	
	WM[1]	PO[2]	WM[1]	PO[2]	WM[1]	PO[2]	WM[1]	PO[2]
Mean	74	43	307	194	186	125	39	19
Minimum	49	23	148	78	93	57	24	1
Maximum	106	103	484	304	442	396	85	47
Standard deviation	14.5	12.6	60.3	40.6	61.7	57.1	10.9	12.9

[1] WM: wholesale markets.
[2] PO: mainly recognized producer organizations.

Table 3. Weekly historical producer price volatility (calculated based on data provided by AMI).

	Apple		Strawberry		Tomato		Onion	
Period (2006–2014)	WM[1]	PO[2]	WM[1]	PO[2]	WM[1]	PO[2]	WM[1]	PO[2]
Volatility %[3]	4a	10b	18a	17a	12a	16b	9a	18b
ADF-Test[4] (Base: prices)	non-stat.	non-stat.	stat.	non-stat.	stat.	stat.	stat.	stat.
ADF-Test[5] (Base: R_t)	stat.	stat.	stat.	stat.	stat.	stat.	stat.	stat.
Period 1 (2007–2010)								
Mean € 100 kg^{-1}	67	39	306	195	177	122	38	18
Volatility %	3	6	19	15	12	16	9	14
ADF-Test[4] (Base: prices)	non-stat.	non-stat.	stat.	stat.	stat.	stat.	non-stat.	non-stat.
Period 2 (2011–2014)								
Mean € 100 kg^{-1}	85	50	307	198	201	135	43	20
Volatility %[6]	4	**14**	16	17	11	16	8	23
ADF-Test[4] (Base: prices)	non-stat.	non-stat.	non-stat.	non-stat.	stat.	stat.	stat.	non-stat.

[1] Wholesale markets.
[2] Mainly recognized producer organizations.
[3] Different letters (a, b) indicate significant differences (Levene's test, 95% significance level) between marketing channels.
[4] Augmented Dickey-Fuller Test to test for stationarity of weekly producer prices (H_0: non-stationary, 95% level of significance).
[5] Augmented Dickey-Fuller Test to test for stationarity of R_t (H_0: non-stationary, 95% level of significance).
[6] Bold numbers indicate significant differences (Levene's test, 95% significance level) between sub-periods.

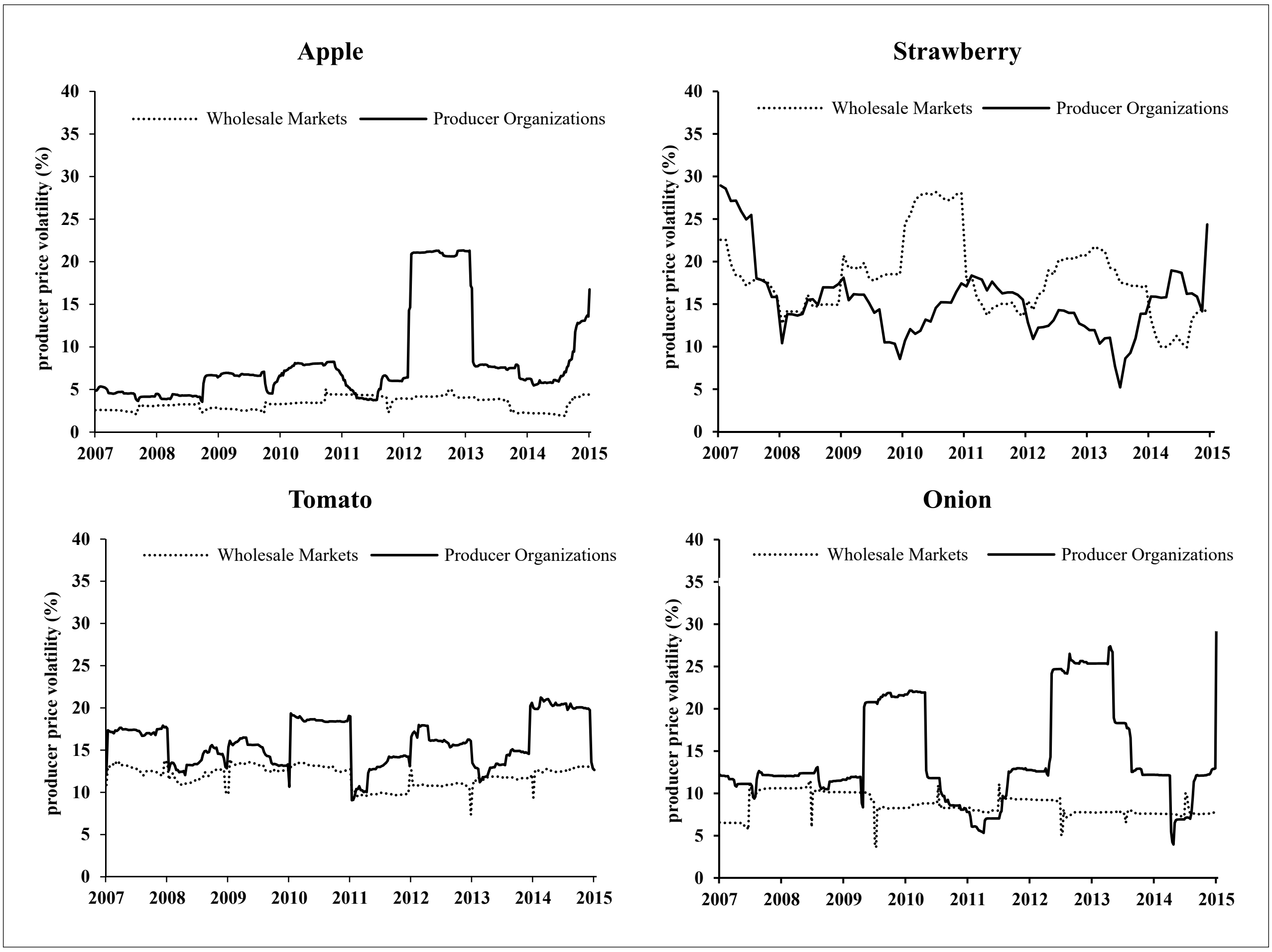

FIGURE 1. Historical producer price volatility based on a 52-week moving window for apples and onions, a 41-week moving window for tomatoes, and a 12-week moving window for strawberries.

organizations face management and governance problems. Because of these limitations, producer organizations are currently not able to use their important position in the value chain for fruits and vegetables effectively enough to provide more stable prices to their members (Gandorfer et al., 2015).

It is further notable that the producer price volatility of strawberries is comparable high. The likely reason is the weather dependency and the short marketing period for strawberries compared to other products, along with their high perishability, and consequently, low storage ability (see Wang et al., 2010). These factors can lead to relatively high producer prices at the beginning, and at the end of the production season in Germany. Together with comparably low prices during production peaks, this results in high producer price volatility. In contrast, producer price volatility of apples is low due to good storage ability, and year-round marketing. Wang et al. (2010), focusing on the Chinese market, found similar results, and identified strawberries as riskier compared to apples in terms price risk. To summarize, the statistical analysis of producer price volatility between crops sold through wholesale markets shows that apple has the lowest producer volatility followed by onion, tomato, and strawberry, respectively. All of the differences in producer price volatility displayed in Table 3 are statistically significant (Levene's test, 95% significance level) with the exception of that between onion and tomato. Apple also shows the lowest producer price volatility when sold through producer organizations. In this case, however, tomato, strawberry, and onion follow (in order of increasing price volatility). Again, all of the differences in producer price volatility displayed in Table 3 are statistically significant (Levene's test, 95% significance level).

Contrary to expectations, a statistically significant increase in producer price volatility from sub-period 1 to sub-period 2 can be observed in only one out of the eight cases analyzed. The increase can be observed in the case of apples sold through producer organizations. The high apple producer price volatility in sub-period 2 is probably associated with supply shocks caused from weather effects. While apple yields in Germany were low in 2010 due to low temperatures and high rainfall during spring (DBV, 2011a), apple yields in 2011 increased. However, they were still below average due to frost and hail events (DBV, 2011b).

In 2012, apple yields were comparable to those of 2011 (DBV, 2013). Apple yields in 2013 were again exceptionally low (17% less than in 2012) due to low temperatures and rainy weather during the flowering stage (DBV, 2013). To summarize, yield variability was much higher in sub-period 2 compared to sub-period 1. It remains unclear why these developments had seemingly only an impact on producer price volatility in the case of selling through producer organizations, and not on selling through wholesale markets. Also, producer price volatility of onions increased from sub-period 1 to sub-period 2 in the case of selling through producer organizations. However, this trend is insignificant. In all other cases, minor decreases and increases of producer price volatilities from sub-period 1 to sub-period 2 are not statistically significant. Gilbert and Morgan (2010, p. 3033) conclude that "There is a general tendency for commentators to assert that food price volatility has increased over time – however, the reverse appears to be true." Although the results of this study do not support the conclusion that the reverse appears to be true, there is little empirical evidence for increasing producer price volatility, at least for the analyzed period and crops, respectively. To provide more detailed insights into the development of producer price volatility over time, producer price volatility is illustrated in Figure 1.

The charts graphically underpin the presented results in Table 3. Producer price volatility is clearly higher when selling through producer organizations compared to selling through wholesale markets in the case of apples, tomatoes, and onions. Only in the case of strawberries, the two lines are crossing several times within the analyzed period, resulting in longer periods where selling through wholesale market shows lower producer price volatility compared to producer organizations. As a result, diversification in terms of selling through both marketing channels reduces price risk in the case of strawberries. The increase of producer price volatility over time is also visible for apples sold through producer organizations (see Table 3).

Conclusions

German fruit and vegetable producers have to deal with high producer price volatility that differs among crops and marketing channels. Therefore, producers can manage their price risk with the decision for a specific marketing channel. Selling through wholesale markets is mostly preferable with respect to producer price volatility. However, it has to be considered that market access through wholesale markets is limited, and therefore, not an option for all producers. Despite the relatively strong position of producer organizations in German fruit and vegetable value chains, they are not successful in terms of generating the most stable producer prices. Therefore, future research could focus on strategies that can help producer organizations to benefit more from their position in the value chain in order to be able to provide more stable prices to their members. In this context, it would be important to analyze strawberries in more detail in order to identify factors that lead to comparable producer price volatilities when selling through wholesale markets and producer organizations.

As stated above, producer organizations play an important role in German fruit and vegetable value chains because they perform various tasks (e.g., risk management, marketing activities, and extension) and, thus, strengthen the position of producers within the value chain. The analysis of risk management instruments provided by producer organizations shows a focus on instruments reducing yield risk (e.g., investment subsidies for anti-hail nets). Thus, specific policy measures should be implemented to encourage producer organizations to focus more on instruments for price risk management. Generally, developing appropriate and innovative price risk management instruments and strategies for fresh produce remains an important task for the future.

Furthermore, our results show that, contrary to popular belief, there is no clear indication that producer price volatility of fruits and vegetables has been increasing in recent years. Observed increases in producer price volatility of apples can be attributed to short-term supply shocks caused by weather events. However, producers of fruits and vegetables have always been exposed to high production risks, and resulting price risk. Nevertheless, it remains a challenge to manage the price risk of perishable fruits and vegetables.

Finally, it can be concluded that distinguishing between horticultural and agricultural crops is essential in the discussion of producer price volatility. Fruit and vegetable producers were consistently exposed to liberalized markets, and therefore, used to higher price risk. For producers of agricultural commodities (e.g., cereals) the recent and ongoing market liberalization together with other reinforcing effects (e.g., bioenergy policy, inventory levels) on price volatility have created a new situation, and thus, raised various stakeholders' attention.

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5 Discussion and conclusions

This dissertation contributes to the agricultural economics risk management literature by providing an in-depth analysis of the risk management of German fruit farms, which has been virtually neglected in research to date. This in-depth analysis involved identifying relevant risk sources, evaluating the risk management instruments applied and conducting a need analysis for developing new risk management instruments or political action to support risk management measures and instruments for this farm type. Depending on the research questions of each study, quantitative and semi-quantitative approaches were applied. The section is structured as follows: first, the main findings of the three studies and their contributions to the existing literature are discussed; second, the current reform proposals for the Common Agricultural Policy after 2020 and selected interest groups are evaluated based on the results of the present dissertation; third, the results of the different approaches are compared and a methodological discussion is conducted, resulting in the call for an integrated risk management process; and finally, the further research and the need for action are derived.

5.1 Main findings and contributions

This chapter contains a discussion based on the three articles in relation to the overall aim of the dissertation. The first study (see chapter 2) provides an overview of the most important risk categories and risk sources of German fruit farms. The most relevant risks are price and production risk, a finding that was expected and confirms prior studies (e.g. Martin, 1996).

In addition, a key finding of the study relates to the strong relevance of the people risk. Thereby, fruit producers distinguished between personal and personnel risk. Risk sources identified for personnel risk included the shortage of seasonal workers, the quality of work as well as the turnover or disability of important non-family employees. Bitsch and Harsh (2004) conducted a study on the single risk sources within the human resource management process with farm managers in the horticultural sector. They also found that a shortage of seasonal workers is a major challenge in horticultural businesses. According to their results, early arrangements with seasonal workers who have already worked for the farm before is a good strategy to mitigate this risk. For the surveyed fruit producers in the present study, the early arrangements with seasonal workers was also a frequently-used and successful instrument to manage this risk. The availability of a qualified workforce is a further major challenge in horticulture. Therefore, the turnover or disability of important non-family employees is a highly-rated risk source. This is in line with Bitsch and Harsh (2004), who found that most qualified workers must work their way up to fit in with the company. As a result, these workers possess a lot of know-how that is difficult to replace quickly. Therefore, job satisfaction plays an important role as a risk management instrument for this risk source. In order to generate job satisfaction, Bitsch and Harsh (2004) recommend training new employees, conducting regular performance evaluations, holding occasional get-togethers and shared meals, showing interest in employees' lives, implementing flexibility in scheduling, sharing business information with employees and providing bonuses.

The personal risk is even more important in fruit production, because most of them are small and medium-sized farms that are highly dependent on the farm manager and the family employees. In order to manage personal risk, farm managers opt for life and accident insurance. From a strategic perspective, farm succession in particular presents a challenge, whereby according to Mair and Bitsch (2018, p. 279) "succession is of exceptional importance". In response to the question of whether farm succession has already been arranged, 33% of the fruit growers surveyed in the present study stated that an arrangement already exists, 15% considered succession as critical and 19% stated that the farm would not be continued. 40% of fruit producers stated that it is not yet necessary to talk about farm succession. This proportion seems very high in relation to the average age of the interviewees, as succession processes take a lot of time (Mair and Bitsch, 2018). Mair and Bitsch (2018) concluded that communication during the succession process is decisive for its success. Communication and transparency are also an important instrument for risk management, especially if the farm is to be continued. In the case of a disability of the farm manager, the documentation of the working processes – and thus the integration of the successor into the farm management – and the issuing of a general power of attorney are important risk management instruments for continuing operations. In practice, however, these instruments have only been used to a limited extent to date (49% of farmers surveyed have a documentation of the working processes).

Personal and marketing risk are two examples highlighting that the assessment of risk categories is insufficient. If only the risk category had been considered, the risk would have been underestimated in both cases. For future applications of the presented framework, an improvement can involve eliminating the first step (assessing the risk categories), because the decision for an appropriate risk management instrument is made based on the single risk source. The benefit of prioritizing risk categories was lower compared with the necessary time to assess the risk categories.

A frequently-mentioned criticism of the use of subjective assessment of risks comprises possible biases, e.g. heuristics or frames (see, e.g. Menapace et al., 2012a, Menapace et al., 2012b). The results showed a strong correlation between the loss experience and the risk assessment, which implies a possible bias in the assessment of risks because fruit producers who suffered from a hail loss rated the hail risk higher than those who did not suffer from a hail loss. This finding confirms Menapace et al. (2012b), who also found that farmers who had yield losses due a hail storm in the past generally rated hail risk higher compared with those in the same region without a hail experience.

The results of the study indicated a strong correlation between the risk categories. The strong correlation between the risk categories requires an overall risk assessment. If only an individual risk assessment is carried out, the response to complex decision-making situations or developments in which several risks influence each other is inadequate.

The analysis of the risk sources within the risk categories showed strong conformity for most of the analyzed risk categories (standard deviation is around 1 in most cases). For example, in terms of production risk, frost and hail are the most relevant risk sources. By contrast, in the price risk category, the farmers showed heterogenous opinions towards risk sources. Risk sources that show a high variance in the assessments within this category included the marketing competence of the producer organization, the concentration process among retailers and the customer dependency, thus indicating that these risks are farm specific.

Diversification is an important strategy in fruit production. The strong relevance of diversification corresponds with other studies in agriculture (Meuwissen, Huirne, and Hardaker, 2001; Koesling et al., 2004; Flaten et al., 2005; Lien et al., 2006; Meraner et al., 2015). According to Meraner et al. (2015), diversification strategies can be divided into three categories: broadening, deepening and re-grounding. Under the category of “broadening”, the authors define all activities that are additional to the farm business, under “deepening”, they understand all activities that are directly connected with the production, while “re-grounding” includes all non-agricultural income opportunities. Diversification through additional activities ("broadening") seems to play a particularly important role, as 75% of all respondents stated that they reduce their entrepreneurial risk through additional branches of business. One motivation might be that the companies surveyed are small and medium-sized family businesses and the number of family employees was relatively high. The family employees are also working to capacity in the off-season due to additional branches of operation. With a high satisfaction level, most fruit growers also seem satisfied with this strategy.

In the deepening category, diversification of marketing channels was the most common activity (68%), followed by diversification across multiple crops (65%) and spatial diversification (51%). In horticultural crops, the advantage of diversification through several marketing channels probably lies in the fact that higher remuneration can be achieved. Better direct marketing options are assumed to lead to higher sales and reduced price volatility.

Meraner et al. (2015) found that the deepening category brings the most benefits on average, whereas the broadening strategy brings only minimal advantages in most cases. The results of the presented study cannot confirm this statement. According to the satisfaction measurement, both the broadening and deepening categories showed high satisfaction values.

Meraner et al. (2015) concluded that the efficiency of the diversification measure depends on whether constant returns are achieved with the diversification alternative and how the result of the risk-reducing activity relates to the operating result. One limitation of the present study is that it did not ask what share of sales the individual activities constitute. However, this information is required for a specific risk strategy recommendation.

The diversification measures in the re-grounding category are the least commonly-implemented measures. The diversification of income through external activities in addition to fruit growing is used by 38% and investments outside the sector by 35%.

In order to manage the main production risk sources, fruit producers can choose between technological and financial risk management instruments. For example, for managing hail risk, hail insurance is still the most common instrument. However, anti-hail nets provide more satisfaction to fruit producers. In terms of frost risk, frost insurance only plays a minor role, whereas frost irrigation is an important risk management instrument. In the current subsidy policy, only technological instruments are supported. The results further confirmed the findings of Vassalos and Li (2016) that there was no significant impact of risk attitudes on risk perception and risk management.

Based on the results of the first study, the second study (see chapter 3) addressed the detected inconsistency between the use of hail insurance and the satisfaction with this instrument, thus contributing to the existing literature comparing technological and financial instruments to manage production risks (e.g. Dalton et al., 2004; Lin et al., 2008; Barham et al., 2011). In general, the higher efficiency of technological instruments compared to financial instruments can be confirmed by the results. However, the results showed that the local risk and the yield potential of the orchard are the key factors for determining the most efficient strategy. The results of this study thus extend beyond the study of Röhrig et al. (2018), who also compared anti-hail nets and hail insurance for German fruit-growing areas. In their study, two fruit-growing regions in Germany were considered: Lake Constance and the Elbe region. Lake Constance is a high-yield, high local hail risk fruit-growing region, whereas the Elbe region is a high-yield but low local hail risk fruit-growing region. They ascertained that in the Lake Constance fruit-growing region anti-hail nets are the best strategy to manage hail risk. Therefore, the results of the present study are in line with Röhrig et al. (2018). However, given that the authors only provided results for subsidized hail insurance in the northern fruit-growing region, a direct comparison with the results for the group of orchards with high yield but low local risk is not possible. The present study`s results extend beyond the findings of Röhrig et al. (2018) because the recommendations are also applicable for other German fruit-growing regions. The present study (chapter 3) also reveals a major advantage of hail insurance compared to anti-hail nets in terms of flexibility. Fruit producers can adjust the insured sum annually, which makes them flexible in years with low expected revenues. For this purpose, they must annually estimate the yields and the expected producer prices and report the expected revenue as the insured sum to the insurance company. However, the analysis of single farms showed that often there is no adaption of the insured sum or the assumed insured sum is incorrect, because prices or yields are over- or underestimated.

In the case of a hail event, the appropriate choice of insured sum is essential for the efficiency of hail insurance. Besides the local risk and yield potential, the appropriate application of the insurance thus also holds importance. This finding is in line e.g. with Salk et al. (2007) and Mouron and Scholz (2008), proposing that knowledge about the instrument is critical for its efficient use.

Besides the economic analysis of anti-hail nets and hail insurance, the marketing channel should also be taken into consideration. The main advantage of anti-hail nets comprises the ability to deliver, which is especially important for farmers selling their apples via wholesale markets, food retailers or use direct marketing.

Based on the results of the first study, the third study (chapter 4) addresses diversification strategies (diversification in crops and diversification in marketing channels) to manage price risk. The knowledge about the producer price volatility of different crops and marketing channels is important for the decision concerning which crops and marketing channels could be combined to reduce price risk. As the results show, producer price volatility differed among crops and marketing channels. The analyzed fruits and vegetables were tomatoes, onions, strawberries and apples. The volatility was highest for strawberries and lowest for apples. These results confirm the study of Wang et al. (2010), categorizing fruits and vegetables in different groups according their seasonality and perishability. The analysis of the marketing channels showed that wholesale markets provide the most stable prices, whereas producer organizations showed a higher producer price volatility. In a further step, the extent to which the producer price volatility has increased during recent years was analyzed. This topic has attracted strong interest in the agricultural economics literature (Gilbert and Morgan, 2010; Balcombe, 2011; Brümmer et al., 2016) due to the strong volatility in the producer prices for cash crops. The results of this study show that for the analyzed fruits and vegetables there was a high price volatility but no significant increase in the volatility in the past nine years. However, temporary demand shocks (e.g. Russia`s import ban on European fresh produce; food crises like E. coli) and supply shocks (e.g. extreme weather events like frost and hail) have occurred and caused high price volatility.

5.2 Evaluation of selected reform proposals for the GAP2020

The importance of risk management for agriculture and horticulture is reflected in the central role that it has played in the Common Agricultural Policy since the last reform. Risk management is also one of the five central thematic areas in the Common Agricultural Policy after 2020 (EC, 2017). The following table presents the reform proposals in the field of risk management by the European Commission and selected interest groups. The first interest group is the Copa-Cogeca, an association of the two large agricultural umbrella organizations in the EU, thus accounting for the strongest representation of the interests of European agriculture. Copa is the European umbrella organization of farmers and Cogeca is the European umbrella organization of agricultural cooperatives. The Bavarian Farmers' Association represents one-third of all farmers in Germany and is thus the largest regional association in Germany. In addition, two relevant fruit-growing regions are within the association's business area. Both the European Commission and the two selected stakeholders have prepared comprehensive reform proposals for the revision of the Common Agricultural Policy after 2020. The reform proposals cover all areas of agriculture and horticulture. However, the design of the reform proposals is primarily developed for the largest target groups of agricultural policy (livestock farmers and cash crop farmers). Based on the results of this dissertation, the reform proposals for risk management are evaluated in terms of their relevance for fruit farms (see **Table 4**).

The table is structured as follows: the reform proposals have been assigned to thematic fields. The cross for the respective interest groups (EC, 2017; CC, 2017; BFA, 2017a; BFA, 2017b) indicates whether the respective stakeholders support the reform proposal. In the "evaluation" column, the proposals are evaluated based on the results of the dissertation.

Table 4. Evaluation of selected reform proposals for the Common Agricultural Policy after 2020 by the European Commission (EC), the Copa-Cogeca (CC) and the Bavarian Farmers` Association (BFA)

Reform proposal	Organizations EC	CC	BFA	Evaluation
Retention of the existing financial support				
Direct payments	X	X	X	Direct payments provide a basic income that ensures stability and liquidity for farmers (EC, 2017). In fruit production, direct payments amount on average to 16% of the total farm income (Porsch et al., 2018a, p. 10), which is low compared to classical cash crop farms, where direct payments amount to over 50% of the farm income (Porsch et al., 2018a, p. 10). The hedging effect of direct payments on stability and liquidity of fruit farms is thus arguable. The results of the survey showed that fruit producer consider the risk associated with the abolition of direct payments to be low, which in turn can be explained by the low hedging effect for fruit farms (Porsch et al., 2018a).
Compensatory payments in a crisis	X	X	X	In recent years, fruit producers have received compensatory payments several times, e.g. due to low producer prices caused by the Russian import ban and a serious frost event in 2017. In both cases, the compensatory payments were the last resort for some farms. Due to the high influence of political events on the business risks (e.g. low producer prices due to the Russian import ban, assumed low producer prices due to the upcoming Brexit) and the lack of nationwide availability of weather insurance (e.g. frost), compensatory payments are important for the stability of fruit farms in a crisis, which exceeds the “normal” entrepreneurial risk.
Subsidies for measures of the second pillar	X	X	X	The second pillar supports many measures that can be used for risk management, such as an anti-hail net subsidies. However, as Porsch et al. (2018b) showed, the anti-hail nets are not always the optimal risk management strategy. DiFalco et al. (2014) and Belasco et al. (2013) also compared different risk management strategies to reduce weather related risks and concluded, that both technical and financial instuments are suitable instruments. The CAP 2020 should thus allow fruit producers to choose between different risk management instruments
Knowledge transfer				
Installing an EU-wide platform for knowledge exchange	X			The results of this dissertation as well as other studies (e.g. Hall et al., 2003; Mouron and Scholz, 2008) show that the correct and efficient use of instruments largely depends on the knowledge about the instrument. Therefore, the EC proposed to install an EU-wide platform for knowledge exchange. According to the reform proposal, the target group comprises farmers, public authorities as well as stakeholders. The platform should provide information on the use of instruments, should improve the use of existing instruments and the information generated on the platform should be used as findings into future policy developments (EC, 2017). Such a platform makes sense to transfer theoretical knowledge into practice. However, the sole installation of a platform does not guarantee that this platform will be used. Consideration should thus be given to what incentives could be provided for the use of this platform.

Reform proposal	Organizations EC	CC	BFA	Evaluation
Producer organizations				
Strengthening producer organizations	X	X	X	Producer organizations play an important role to strengthen the position of farmers in value chains (Gandorfer et al., 2016). Especially for small farmers, they are important because due to quantity requirements they often do not have access to marketing via wholesale markets (Gandorfer et al., 2016). 54% of farmers sell their fruits through producer organizations. It is important that producer organizations can guarantee stable prices because this is the most attractive marketing channel, especially for small and medium-sized farms, which are the target group of producer organizations.
Facilitating exports to third countries	X	X	X	Gandorfer et al. (2016) showed that the economic success of producer organizations and the export activities of producer organizations are linked. Therefore, the export to third countries should be facilitated.
More flexibility in the use of the funds granted, e.g. salary for professionals within the producer organization		X		Another success factor for producer organizations is the professional management (Gandorfer et al., 2016). One way to improve the producer organizations' market position is to internationalize the producer organization. However, the study conducted by Gandorfer et al. (2016) has shown that this strategy requires a high level of expertise on the part of the managing director. Furthermore, the study found a positive correlation between the proportion of employees with international experience and turnover. Gandorfer et al (2016) concluded that the qualifications of employees thus hold strong importance and that appropriate remuneration is also necessary to attract these personnel. Therefore, the proposal of Copa-Cogeca (CC, 2018) that the funds granted for producer organizations could be used more flexibly is an important proposal, which should find its way into the Common Agricultural Policy after 2020.
Subsidization of risk management instruments				
Multiple-peril insurance			X	In contrast to many other EU countries, there is no subsidy for multiple-peril crop insurance in Germany, because the efficiency of the subsidization of this instrument has been doubted (WB, 2011). In contrast to cash crops, only one insurance company provides insurance coverage for frost risk in Germany. In order to enlarge the supply of frost insurance, a temporary subsidy of multiple-peril crop insurance should be considered.
Price transparency				
Introduction of binding price reporting		X	X	In contrast to cash crops, there are no future markets for fruits and vegetables, which is seen as one reason for the high producer price volatility in the fruit and vegetable sector (Manfredo and Libbin, 1998). The introduction of binding price reporting is a possibility to create more transparency for fruit farmers and may reduce price risk. In fruit production, only one initiative – the listing of pome fruits for the Lake Constance region – exists that enables fruit farmers high transparency on apple prices. The listing is a voluntary institution supported by representatives of the industry (fruit producers organizations, wholesale markets) and the federal state. This successful model should also be applied to the other federal states in Germany and furthermore

Reform proposal	Organizations EC	CC	BFA	Evaluation
				extended to include additional crops.
Market power of food retailers				
Legislative measures to reduce the market power of highly-concentrated food retailers			X	Nearly 90% of fresh fruits are sold via food retailers to the consumer (Behr, 2014). As a result, food retailing occupies a dominant position in the value chain. According to Steinborn and Bokelmann (2007), the ongoing concentration process of food retailers leads to further pressure on producer prices. Therefore, the BFA proposed legislative measures to limit the market power of food retailers (BFA, 2018). In April 2018, the EC (EC, 2018) presented a first draft of the directive against unfair trading practices for the Common Agricultural Policy after 2020. In order to strengthen the position of farmers in the value chain, unfair trade practices are to be punishable. Examples of unfair trade practices in the reform proposal include “late payments for perishable food products, last minute order cancellations, unilateral or retroactive changes to contracts, and forcing the supplier to pay for wasted products” (EC, 2018). The EC’s proposal requires member states to appoint an authority to ensure compliance with the directive. If there is an infringement, the authority may impose a "proportionate and dissuasive sanction” (EC, 2018). The push to limit market power and thus improve the position of fruit growers is an important step towards improving the position of fruit growers in the value chain. It remains to be seen whether such a directive will actually improve the position of fruit growers in the value chain.

5.3 Methodological discussion

Within this dissertation, different research methods have been applied to study the individual research questions. These methods can be assigned to quantitative and semi-quantitative methods (see e.g. Peeler et al., 2015; Hardaker and Lien, 2010). In the following section, this dissertation draws a further conclusion on an overarching “meta-level” regarding the methods applied to analyze the risk management of fruit farms. Therefore, the results in terms of hail risk management and price risk management are compared between the first study (semi-qualitative) and the second and third studies (quantitative approach).

Whereas in the first study the research interest comprised the question of which instruments are applied and how satisfied the fruit producer are with them, in the second and third studies an economic analysis considering risk was conducted. The first comparison comprises the juxtaposition of the hail risk management instruments applied and the satisfaction with them (**study 1**), as well as the efficiency of different hail risk management instruments depending on farm characteristics and risk aversion (**study 2**). In a second step, the survey results of the assessment of satisfaction with diversification (marketing channels, crops) to manage price risk are compared with the results of the volatility analysis of producer prices for different crops and marketing channels (**study 3**). The comparison of the respective studies is based on the type of data, the method, the period under consideration, possible biases and the results (see Table 5 and 6).

Table 5: Comparison of hail risk assessment and hail risk management evaluation using quantitative and semi-quantitative approaches

	Quantitative (objective probabilities)	**Semi-quantitative (subjective probabilities)**
Data	Hail statistic , dataset of insurance data regional yield data, German producer prices	Survey data
Period of data collection	10 years	One year
Bias	Under-/over-estimation of risk due to aggregation level of yield data	High correlation with loss experience
Method	Expected utility model	Measurement of the farmers‘ satisfaction with the applied risk management instruments
Results	Optimal hail risk management strategy depends on the local hail risk and yield potential: Group 1 (low hail risk, low yield potential): no hail risk management is the most efficient strategy Group 2 (low hail risk, high yield potential): the use of an anti-hail net is the most efficient strategy, but with increasing risk aversion, hail insurance is most efficient Group 3 (high local risk, low yield potential): the use of a hail insurance is the most efficient strategy Group 4 (high hail risk, low yield potential): the use of an anti-hail net is the most efficient strategy The individual case analysis shows that the choice of the right sum insured is decisive for the efficiency of hail insurance. However, this is often not adjusted, or the expected yield or price is over- or underestimated. This leads to either an expensive premium or a reduced compensation payment.	Hail insurance (75%) is used more often compared to anti-hail nets (27%) Satisfaction with anti-hail nets is higher compared to hail insurance Some farms (16%) use both hail insurance and anti-hail nets
Role of risk attitude	Only in group 2	No significant influence

In the first of the three studies presented, an analysis of the entire risk management process of fruit farms was conducted to generate broad insights into the risk management process. With the presented framework, a risk management process can be implemented in small and medium-sized family fruit farms and thus the most important risks can be identified and suitable instruments can be selected and regularly monitored with an assessment of satisfaction. The use of subjective probabilities enables assessing risks and risk management instruments due to the limited requirements for data availability. However, there is some evidence of biases, which is typical for the subjective probability approach, e.g. the strong correlation between loss experience and the rating of single risks. These biases may lead to a non-economically-optimized decision when choosing a risk management instrument (e.g. anti-hail nets versus hail insurance), because the risk is either overestimated or underestimated.
As the comparison shows, significantly more input variables are required for the expected utility model (quantitative approach) to answer the question of which strategy is more efficient to mitigate hail risk. Moreover, in order to analyze the producer price volatility, the data requirements are high.
Another difference between the research methods relates to the period under consideration. The survey only asks for a one-year period, which could possibly lead to a bias given that the assessment depends on experience. For example, if a hail risk has recently occurred, the respondent will probably assess the hail risk more highly. For the quantitative studies, the period of data collection is much longer. The reason for a potential bias in the quantitative approach is found in the data: due to the lack of farm-level data, aggregated data must be used for yields and prices. In both cases (quantitative and semi-quantitative approach), the bias may lead to an over- or underestimation of the risk. Comparing the results of the studies in terms of hail risk management, risk attitudes do not play role in either study. In the first study, no significant influence was found. In the second study, the risk attitude only has an influence at a high degree of risk aversion in a single group (low yield, high hail risk).
In both cases, the different methods applied to a similar research question enhanced the knowledge about the topic. In the case of hail risk management, the observed inconsistency between the use of hail insurance and the low satisfaction with it could be explained by the expected utility analysis in study 2. The results of the expected utility model showed that the two instruments are not equally suitable for every orchard, whereby the efficiency depends on the local hail risk and the yield potential, as well as the variety and the marketing channel. A biased risk assessment or a simplified comparison calculation could possibly lead to an incorrect decision, which would explain the inconsistency between the use and satisfaction.
In the case of price risk mitigation, the different methods applied show similar results. The surveyed farmers are satisfied with the diversification of crops and marketing channels. As the

results of the producer price analysis show, crops and marketing channels considerably differ in terms of producer price volatility. A sensible combination of different crops and marketing channels can thus reduce the price risk.

Table 6. Comparison of price risk assessment and price risk management evaluation using quantitative and semi-quantitative approaches

	Quantitative (objective probabilities)	Semi-quantitative (subjective probabilities)
Data	Time series of producer prices	Survey data
Period of data collection	Nine years	One year
Bias	Aggregation level of data	Strong correlation of assessment of the price risk and loss experience
Method	Analysis of the producer price volatility for different marketing channels and crops	Measurement of the farmers' satisfaction with the applied risk management instruments (diversification of crops, marketing channels)
Results	Different marketing channels as well as crops show different degrees of volatility	High satisfaction with diversification of crops and of marketing channels

According to Creswell and Plano Clark (2011), the enhancement of knowledge is one of six reasons for the demand for integrating survey methods and quantitative methods. The other five reasons are summarized by Akimowicz et al. (2018) as follows: "[…] a single data source may be insufficient, […] initial results need to be explained, […] exploratory results need to be generalized, […] a theoretical stance is best employed with qualitative and quantitative results and multiple research phases help to understand a research object better" (Akimowicz et al., 2018, p. 3). Therefore, an integrative approach might be useful to compare the relevant perceived risks with objective data. With an integrated approach, the advantages of both approaches can thus be used. However, it must be considered that an integrated approach also results in a high level of effort due to the required knowledge about different research methods and the resources needed for the research. Especially in terms of risk behavior, there is often a mismatch between research and practice. The validity and reliability may be improved by the use of an integrated approach (Akimowicz et al., 2018, p. 9) and can thus possibly reduce these inconsistencies.

5.4 Practice implications and further research

Small and medium-sized fruit farms would benefit from professional risk management in different ways. Most business-relevant risks are risks that affect the farm from outside (e.g. price risk, production risk). An appropriate risk management process leads to the early identification of these risks and thus facilitates their management applying appropriate risk management instruments. Appropriate instruments can reduce costs and prevent damage to the farm.

However, the implementation of a farm risk management process remains a major challenge for small and medium-sized farms. Nevertheless, the recent developments (e.g. the Russian import ban, weather extremes and the upcoming Brexit) show that appropriate risk management is becoming increasingly important. Adapted to the needs of fruit farmers, a framework – such as the one presented in the first study – should be digitally implemented in a farm management system. Farm management systems are "electronic tools for data collection and processing with the goal of providing information of potential value in making management decisions" (Fountas et al., 2015, p.41). Fountas et al. (2015) conducted an analysis of 141 farm management information systems and found that most of them (85%) are specialized in field production. Further functions include sales, human resource management, machinery management, reporting and finance. Fountas et al. (2015) criticized that "the current situation in European farming is that most data and information sources are fragmented, dispersed, difficult and time-consuming to use" (Fountas et al., 2015, p. 40). Therefore, farmers need a farm management system, which addresses all relevant management tasks for their farm. This farm management system should also include a risk management module. The successful integration of a risk management module into the farm management system has the consequence that decisions can be made based on ever-larger amounts of information. This will improve the basis for decision-making for the farmer and will help to optimize decisions regarding risk management.

A major finding of the first study was the strong relevance of people risk. Although people risk is mentioned in some studies (e.g. Martin, 1996; Catalá et al., 2013), it is not well studied generally across literature. An important result is that fruit farmers distinguish between personnel and personal risk. The main risk sources within the personnel risk are the shortage of seasonal workers, the turnover or disability of non-family employees and a low quality of work. These findings are in line with Bitsch and Harsh (2004) and the instruments (e.g. job satisfaction, early arrangements with seasonal workers) recommended in the study of Bitsch and Harsh (2004) are the most commonly-used instruments to handle personnel risk in study 1. In terms of personnel risk, farmers need more support to comply with legal requirements to employ non-EU citizens, which will become an important challenge in the future when fewer seasonal workers will come from EU neighbors due to the good economic situation. Already in 2018, there was a shortage of seasonal workers for the strawberry and asparagus harvest. Moreover, qualified non-family employees are also in short supply, whereby the sector faces a challenge in recruiting a sufficient number of junior staff members.

As Mair and Bitsch (2018) stated, succession will become one of the most important topics of the future in horticulture. In terms of risk management, more attention should be devoted to on-farm risk management instruments for personal risk, such as an emergency response plan or a general power of attorney. This is not only an effective instrument in case of a disability of the farm manager or an important family employee, but it also promotes communication between the farm manager and a potential successor. According to Mair and Bitsch (2018), this is an important factor for a successful succession process.

In the second study, a detailed analysis of hail risk management was presented. Depending on farm characteristics (initial wealth, yield potential, local hail risk), hail insurance and anti-hail nets were compared in terms of the most efficient risk management strategy. There is no uniform recommendation that is suitable for all farms; therefore, subsidy programs should be more flexible. At present, only technologies (anti-hail net) can be subsidized. Especially in tourist regions, anti-hail nets are often criticized for having negative effects on the landscape. In most cases, hail insurance is a viable alternative to anti-hail nets (in terms of differences between certainty equivalents), except for orchards with a high yield and a high local hail risk. Research in horticultural production technology should thus focus on developing anti-hail nets with less impact on the landscape.

Besides hail, frost is the most important risk source in fruit production. A technical (frost irrigation) and financial (frost insurance) instrument for risk reduction is available to manage this risk. There is no economic analysis analyzing the optimal risk management strategy for frost risk. In terms of the Common Agricultural Policy after 2020 and the call for a subsidy of frost insurance, in future research frost irrigation and frost insurance should be compared. Such a study should also include an analysis of the optimal combination of risk management strategies for hail and frost risks.

Diversification is the main risk management strategy in fruit farming, whereby especially the diversification of crops and marketing channels are most frequently used. Study 3 should be extended to include further crops and marketing channels. Given that diversification is the only instrument to manage the price risk, knowledge of producer price volatility is necessary to find risk-reducing combinations for fruit farms.

The overall conclusion from this dissertation is that risk management is an important topic for fruit production. Study 1 revealed the major risks in fruit production, the instruments applied and fruit producers' satisfaction with them, as well as presenting a framework for small and medium-sized farms to implement a risk management process. Study 2 analyzed the most efficient strategy for hail risk management depending on farm specifics and risk aversion, as well as contributing to prior research comparing technological and financial instruments for risk mitigation. In study 3, the producer price volatility of different crops and marketing channels was analyzed. The findings offered important insights into possible combinations of crops and marketing channels to reduce price risk. The current reform proposals for the Common Agricultural Policy after 2020 regarding risk management were evaluated based on the results of this dissertation. Comparing the studies included in this dissertation highlights the need for an integrated approach of quantitative approaches and a subjective survey. Such an integrated approach will help to close the gap between researchers and practitioners by increasing the validity and reliability of research results.

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