Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute)
University of Hohenheim
Department of Rural Development Theory and Policy
Prof. Dr. Manfred Zeller

Analysis of factors driving differences in intensification and income from agriculture among smallholder farmers in Northern Vietnam

Dissertation
Submitted in fulfilment of the regulations to acquire the degree
"Doktor der Agrarwissenschaften"
(Dr. sc. agr. in Agricultural Sciences)

to the
Faculty of Agricultural Sciences

presented by

Susanne Ufer
Born in Zittau, Germany

-2021-

This thesis was accepted as a doctoral thesis (Dissertation) in fulfilment of the regulations to acquire the doctoral degree "Doktor der Agrarwissenschaften" (Dr. sc. agr.) by the Faculty of Agricultural Sciences at the University of Hohenheim on 20 September 2021.

Date of oral examination: 22 October 2021

Examination Committee

Chairperson of the oral examination	Prof. Dr. Andrea Knierim
Supervisor and Reviewer	Prof. Dr. Manfred Zeller
Co-Reviewer	Prof. Dr. Steffen Abele
Additional examiner	Prof. Dr. Georg Cadisch

Table of Contents

Acknowledgements .... **iii**

Executive Summary .... **iv**

Zusammenfassung .... **vii**

List of Figures .... **xi**

List of Tables .... **xii**

Abbreviations .... **xiii**

1. Introduction **1**

1.1. Problem setting 1

1.2. Research focus 5

1.2.1. The importance of technology adoption for agricultural productivity growth 5

1.2.2. Factors affecting technology adoption 6

1.2.3. Thesis objective, research questions, and hypotheses 12

1.3. Survey implementation 14

1.3.1. Description of the research area 14

1.3.2. Data collection 15

1.3.3. Research design and sample selection 16

1.4. Outline of the thesis 16

2. Level and short-term changes in input use and agricultural productivity of maize **17**

2.1. Introduction 17

2.2. Conceptual framework and methodology 19

2.2.1. Conceptual framework 19

2.2.2. Empirical strategy and methodology 20

2.2.3. Description of the regression samples 22

2.3. Presentation of empirical results 23

2.3.1. Agricultural system and household characteristics 23

2.3.2. Maize production 27

2.4. Discussion of results and research and policy conclusions 47

3. Impact of risk aversion on fertiliser use: Evidence from Vietnam **54**

3.1. Introduction 54

3.2. Conceptual framework 55

3.3. Empirical study 57

3.3.1. Fertiliser use intensity 57

3.3.2. Risk preference 57

3.3.3. Wealth 58

3.3.4. Control variables 60

3.4. Results and discussion 63

3.4.1. Other measures of fertiliser use intensity 66

3.4.2. Other measures of wealth 66

3.5. Conclusions 67

4. Determinants of agricultural productivity – decomposition analysis of maize income of smallholder farmers in Northern Vietnam 68

4.1. Introduction 68

4.2. Conceptual and methodological framework 70

4.3. Empirical study 73

4.3.1. Description of the regression sample 73

4.3.2. Variables describing household wealth 73

4.3.3. Description of variables included in the regression and decomposition analysis 74

4.4. Results and discussion 77

4.4.1. Explanation and discussion of regression results 77

4.4.2. Explanation and discussion of decomposition results 89

4.5. Summary and implications for research and policy 100

5. Summary 104

5.1. Introduction 104

5.2. Summary of main empirical findings of the doctoral thesis 105

5.3. Overall discussion and policy conclusions of the doctoral thesis 109

5.3.1. Improving the scope and quality of research and extension 109

5.3.2. Helping poor households to deal with downside risks 110

5.3.3. Acknowledging the importance of assets for agricultural productivity 111

5.3.4. Improving long-term prospects of agricultural production and rural development in the Northern Uplands 113

References 115

Appendices 124

Appendix A: Selection model 124

Appendix B: Questionnaires 126

Acknowledgements

This doctoral thesis is the outcome of my PhD research conducted at the Department of Rural Development Theory and Policy of the Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute) at the University of Hohenheim, Germany. The doctoral thesis was executed in the framework of the special research program SFB 564, also known as the "Uplands program", financed by the DFG, whose financial support is gratefully acknowledged. First of all, I would like to express my gratitude to my first supervisor Prof. Dr. Manfred Zeller for his excellent academic advice, his supervision, and his endurance over the long finishing period of my thesis. I also would like to thank him, Prof. Dr. Abele, and Prof. Dr. Cadisch for reviewing my thesis and taking part in my PhD committee. I also would like to thank my working colleagues Alwin Keil, Camille Saint-Macary, Le Thi Ai Van, Dinh Thi Tuyet Van, and Thea Nielsen from the Department of Rural Development Theory and Policy that participated like me in the Department's Uplands program for their great colleagueship, inspiring discussions, and the profound introduction to the Uplands program as well as to Vietnamese culture. Further working colleagues I would like to thank are Ling Yee Khor and Thea Nielsen for great research cooperation as well as my colleagues Thomas Gut, Michael Hagemann, Volker Häring, Nguyen Thi Thanh, and Johannes Pucher for general academic exchange and friendship during my time at the University of Hohenheim. A special thanks goes also to the leadership and administrative staff involved in the Uplands program that made every stay in Vietnam a fruitful experience, in particular Gerhard Clemens, Prof. Pham Thi My Dung, and Mrs. Hong. I am also grateful and would like to especially thank my field assistance staff, my team of local enumerators, my team of data entry operators, the local officials, as well as all the participants of the survey without whom this thesis would have not been possible, for their effort and time devoted to supporting the survey. Many thanks go also to my parents, family, and my friends outside the university, who have supported, accompanied, and encouraged me throughout this process.

Executive Summary

Challenged by difficult topography, remoteness, high ethnic diversity, low levels of infrastructure, high poverty, and high dependency on upland farming systems the well-being and incomes of ethnic minorities and the poorest in the Northern Uplands of Vietnam, like in many upland areas in Southeast Asia, are still predominantly linked to agricultural productivity. At the same time agricultural commercialization, the introduction of modern agricultural technologies, higher input use, and stronger agricultural specialization have increased the demands on households' ability to adequately invest in agricultural intensification and to protect themselves from agricultural income risks. In the Northern Uplands, one of these extensively cultivated, highly commercialized, and highly specialized upland crops is maize. A crop that needs high levels of inputs and is predominantly grown for cash income from poor and non-poor farmers alike.

Given the low asset levels of households, it is therefore of particular interest which differences in challenges farmers may face regarding the improvement of maize production dependent on their wealth level. Yet, no detailed research exists that analyses how the level of asset endowments with natural, human, physical, financial, and social capital as well as risk aversion impact technology adoption, maize intensification, and maize productivity of farmers of different household wealth. This doctoral thesis seeks to fill these knowledge gaps by investigating the following research topics: (1) the level and short-term changes in agricultural input use and productivity in maize production by household wealth, (2) the impact of risk aversion on fertiliser use in maize production by household wealth, and (3) the impact of household asset levels and the return to assets on productivity differences in maize production between households of different wealth.

Research analysis builds on a quantitative dataset collected from a random panel sample of 300 rural households in Yen Chau district, Son La province, in the Northern Uplands of Vietnam in the period from 2007 to 2010. The research area is relatively poor, ethnic diverse, with a high dependency on upland agriculture, crop income, and maize income in particular. Econometric analysis is carried out firstly by organizing households by wealth through a composite asset-based indicator derived from principal component analysis (PCA) and secondly by applying extensive descriptive analysis, regression analysis, and econometric decomposition-based techniques to the so differentiated dataset.

Results from the first research topic (1) "Level and short-term changes in agricultural input use and productivity in maize production by household wealth" show that average numbers on maize input use, maize productivity, and maize income hide important wealth-related differences. While adoption rates of modern maize seeds and mineral fertilisers are widespread and very similar by wealth terciles over time, input use intensity of fertilisers, maize yields, and maize incomes differ significantly between the poorest tercile and the wealthier maize farmers. While a substantial share of the poorest household tercile uses fertiliser quantities well below recommended levels, households of the middle and wealthiest

terciles are about twice as likely to apply fertilisers according to average or above-average fertiliser recommendation levels. Moreover, between approximately one-tenth and one-quarter of households from all wealth terciles overuse fertiliser, too. The poorest tercile further buys despite the lower use of fertilisers more often seed and fertiliser inputs on-loan than households from higher wealth terciles. Consequently, the poorest households have to pay relatively higher input costs at otherwise mostly similar market prices for seed and fertiliser inputs and maize output. Yield, input price, and output price risks are high in the research area for all households. However, the poorest tercile of households suffers somewhat more from risks due to fluctuations in yield, output price, and maize income.

Results from the second research topic (2) "Impact of risk aversion on fertiliser use by household wealth" show that the fertiliser quantity applied to maize is affected by the risk aversion of the household head in the poorest one-third of households and not affected by the risk aversion of the household head of the wealthier households. The results remain valid when different empirical risk aversion measures (i.e. self-assessment scale and lottery game) are considered, when instead of total fertiliser quantity, the quantity of NPK, urea, or total nitrogen are considered, as well as when different measures of household wealth are considered (i.e. asset-based wealth index, household per-capita income, and household per-capita consumption expenditure).

Results from the third research topic (3): "Impact of household asset levels and the return to assets on productivity differences in maize production between households of different wealth" show that quantity-based assets effects are more important for the size of the maize income gap per hectare between the poorest one-third of maize farmers and maize farmers of higher wealth than the return-based assets effects. Quantity-based asset effects significantly account for more than two-thirds of the entire maize income gap, while return-based assets effects are on the contrary not statistically significant at all. From the quantity-based assets effects, credit limit, ethnicity of the household head, and upland land value have large and significant effects. Farm size, value of buffalo and cattle, and household head age have smaller and less constant effects. Credit limit is the most important and most consistent driver by size, showing that financial access for poor minority households is still a defining obstacle to agricultural productivity. Ethnicity of the household head has a strong and positive but decreasing impact on the maize income gap, showing that ethnicity-related soft factors, such as differences in location, agricultural practices, and traditions, should be taken more into acknowledgement. From the significance of the upland land value, we conclude that environmental factors, such as the prevention of soil erosion, the protection of soil fertility, and considerations of long-term sustainability, should gain more emphasis. Other minor factors driving the maize income gap are discussed in more detail in the thesis.

From the results of the doctoral thesis, we draw the following main conclusions for the development of pro-poor strategies for the improvement of upland agricultural productivity.

Firstly, agricultural research and extension should pay more attention to identifying bottlenecks households face dependent on their wealth level to avoid overseeing the specific obstacles poor and non-poor farmers face that may result in the perpetuation of poverty traps, increased inefficiency, and the waste of resources. Consequently, more emphasis is needed on research and extension that incorporate wealth-related agronomic, financial, and risk-related aspects, that better account for the efficient use of inputs, and that place increased emphasis on the adaptation of technological innovations to the farm systems and needs of upland minorities.

Secondly, more emphasis should be placed on helping poor households to deal with risks. While all households face yield, input and output price risks, risk aversion affects input intensification decisions in the poorest one-third of households. Hence, especially for the poorest more emphasis should be placed on the expansion of risk management options that account for the lower risk-bearing capacity and higher risk aversion of the poor, and the often higher transaction costs. This includes measures such as improving the financial literacy of households, allowing households to borrow for consumption, linking credit with insurance or saving options, decreasing transaction costs and the complications linked with successfully applying for loans, as well as, if possible, developing innovations like improved seeds or agricultural management systems that have the capacity to lower the downside risks of production.

Thirdly, assets should be considered an important driver of agricultural productivity differences between poor and non-poor farmers. Based on the findings that the quantity-based effects of assets are the major and only significant driver of the maize income gap between the poor and non-poor maize farmers, we conclude that the poorest households can have the same productive agricultural potential as the non-poor if they would have the same level of assets. Supporting households to get access to and accumulate assets should be therefore an important policy goal. This is particularly true about assets that can be influenced by agricultural research, improved agricultural extension, and targeted development policy. Based on our research findings this concerns the improvement of access to credit, the support of ethnic minority households, and efforts to increase the sustainability of upland agriculture.

Fourthly, investing in the long-term suitability of maize production and upland farming systems is recommended. While maize can be a very profitable cash crop in the short run, the results of this doctoral thesis also show that a strong specialization in maize production may embody multiple short-term and long-term economic as well as sustainability related livelihood risks. This includes the possibly limited extent of the profitability of additional credit and inputs as well as a strong dependency on the quality of natural resources. In consequence, policies should focus on directly improving the conditions for maize productivity as well as improving the conditions for long-term development. Such measures include supporting households to invest more in profitable on-farm and off-farm diversification, the improvement of infrastructure and extension to increase the profitability of unused cropping choices, the development of profitable soil protection measures, and investments in education and the development of off-farm job alternatives.

Zusammenfassung

Bedingt durch schwer zugängliche Topografie, Abgeschiedenheit, hoher ethnischer Diversität, niedrigem Infrastrukturniveau, hohen Armutsraten und einer starken Abhängigkeit von Hochlandagrarsystemen hängen das Wohlergehen und die Einkommen der ethnischen Minderheiten und der Ärmsten in den Nördlichen Bergregionen von Vietnam, wie in vielen Bergregionen Südostasiens, nach wie vor überwiegend von der landwirtschaftlichen Produktivität ab. Gleichzeitig haben die Kommerzialisierung der Landwirtschaft, die Einführung moderner landwirtschaftlicher Technologien, ein steigender Betriebsmitteleinsatz und eine stärkere landwirtschaftliche Spezialisierung die Anforderungen an die Fähigkeiten der Haushalte erhöht, ausreichend in die landwirtschaftliche Intensivierung zu investieren und sich von landwirtschaftlichen Einkommensrisiken zu schützen. Eine dieser in den Nördlichen Bergregionen weitverbreitet angebauten, stark kommerzialisierten und stark spezialisierten Hochlandpflanzen ist Mais. Eine Feldfrucht, welche eines hohen Betriebsmitteleinsatzes bedarf und die hauptsächlich für die direkte Vermarktung von ärmeren wie wohlhabenderen Landwirten angebaut wird.

Ausgehend von der geringen Ressourcenausstattung der Haushalte ist es deswegen von besonderem Interesse, mit welchen Unterschieden in den Herausforderungen Landwirte bei der Verbesserung des Maisanbaus in Abhängigkeit von ihrem Wohlstandsniveau konfrontiert sind. Dennoch existieren zum jetzigen Zeitpunkt keine detaillierten Forschungsergebnisse, welche untersuchen, wie sich die Ausstattung mit natürlichen, humanen, physischen, finanziellen und sozialen Ressourcenkapital sowie die Risikoaversion auf die Nutzung neuer Technologien, die Intensivierung des Maisanbaus und die Maisproduktivität der Haushalte in Abhängigkeit von Ihrem Wohlstandsniveau auswirken. Diese Dissertation versucht diese Wissenslücken zu schließen, indem sie die folgenden Forschungsthemen untersucht: (1) Niveau und kurzfristige Änderungen im landwirtschaftlichen Betriebsmitteleinsatz und der Produktivität im Maisanbau in Abhängigkeit vom Wohlstandsniveau der Haushalte, (2) Einfluss der Risikoaversion auf den Düngemitteleinsatz im Maisanbau in Abhängigkeit vom Wohlstandsniveau der Haushalte, und (3) Einfluss der Ressourcenkapitalausstattung und des Ressourcenkapitalertrags auf die Produktivitätsunterschiede im Maisanbau zwischen Haushalten mit unterschiedlichem Wohlstandsniveau.

Die Analysen der Dissertation basieren auf einem quantitativen Datensatz, der im Rahmen einer Panelhaushaltsumfrage, basierend auf 300 zufällig ausgewählten ländlichen Haushalten im Bezirk Yen Chau, Provinz Son La in den Nördlichen Bergregionen Vietnams im Zeitraum von 2007 bis 2010 erhoben wurde. Das Forschungsgebiet gehört zu den ärmeren Landstrichen der Nördlichen Bergregionen, geprägt durch eine hohe ethnische Diversität sowie einer starken Abhängigkeit von der Hochlandfeldbewirtschaftung, dem Feldfruchteinkommen und dem Maiseinkommen im Besonderen. Für die ökonometrischen Analysen werden zuerst die Haushalte anhand eines zusammengesetzten, vermögensbasierten Wohlstandsindikators, welcher mit Hilfe einer Hauptkomponentenanalyse errechnet wurde, ihrem Wohlstand nach

geordnet und zweitens der so differenzierte Datensatz anhand ausführlicher deskriptiver Statistiken sowie Regressions- und Dekompositionsanalysen untersucht.

Die Ergebnisse des ersten Forschungsthemas (1) „Niveau und kurzfristige Änderungen im landwirtschaftlichen Betriebsmitteleinsatz und der Produktivität im Maisanbau in Abhängigkeit vom Wohlstandsniveau der Haushalte“ zeigen, dass auf dem Durchschnitt basierende Analysen zum Betriebsmitteleinsatz, der Produktivität und dem Einkommen im Maisanbau wichtige vom Wohlstandsniveau abhängige Unterschiede verbergen. Während die Adoptionsraten von modernem Maissaatgut und mineralischen Düngemitteln weitverbreitet und im Laufe der Zeit sehr ähnlich in allen Wohlstandstertilen sind, unterscheiden sich die Intensität des Düngemitteleinsatzes, die Maiserträge und die Maiseinkommen zwischen dem ärmsten Wohlstandstertil und den wohlhabenderen Landwirten signifikant. Während ein großer Anteil der Haushalte des ärmsten Wohlstandstertils Düngemittel erheblich unterhalb der empfohlenen Düngemittelmenge einsetzt, ist es in den Haushalten aus den mittleren und wohlhabendsten Tertilen ungefähr doppelt so wahrscheinlich, Düngemittel gemäß oder über der durchschnittlich empfohlenen Düngemittelmenge zu nutzen. Darüber hinaus weisen ungefähr ein Zehntel bis ein Viertel der Haushalte unabhängig vom Wohlstandstertil einen überhöhten Düngemitteleinsatz auf. Haushalte aus dem ärmsten Tertil kaufen zudem trotz ihres geringeren Düngemitteleinsatzes häufiger Maissaatgut und Düngemittel mit der Hilfe von Kredit als die Haushalte aus den wohlhabenderen Tertilen. Als Folge müssen die ärmsten Haushalte vergleichsweise höhere Preise für den Erwerb von Betriebsmitteln zahlen, bei ansonsten meist ähnlichen Marktpreisen für den Kauf von Maissaatgut- und Düngemitteln sowie dem Verkauf von Mais. Ertrags-, Betriebsmittelpreis- sowie Maisverkaufspreisrisiken sind für alle Haushalte im Forschungsgebiet hoch. Haushalte aus dem ärmsten Tertil leiden jedoch etwas stärker unter den Risiken, die sich aus den Schwankungen von Ertrag, Verkaufspreis und Maiseinkommen ergeben.

Die Ergebnisse des zweiten Forschungsthemas (2) „Einfluss der Risikoaversion auf den Düngemitteleinsatz im Maisanbau in Abhängigkeit vom Wohlstandsniveau der Haushalte“ zeigen, dass die Menge an genutzten Düngemitteln im Maisanbau von der Risikoaversion des Haushaltsvorstands im ärmsten Wohlstandsdrittel der Haushalte beeinflusst wird, während die Menge der genutzten Düngemittel in den wohlhabenderen zwei-Dritteln der Haushalte von der Risikoaversion des Haushaltsvorstands unbeeinflusst bleibt. Diese Ergebnisse behalten ihre Gültigkeit unabhängig davon, welche empirische Risikoaversionsmethode verwendet wird (d. h. Selbsteinschätzungsskala oder Lotterieergebnisse), wenn anstatt der Gesamtdüngemittelmenge, die NPK-Düngemittelmenge, die Urea-Düngemittelmenge oder die Gesamtstickstoffmenge betrachtet wird, sowie wenn unterschiedliche Methoden zur Messung des Haushaltsvermögens betrachtet werden (d. h. der vermögensbasierte Wohlstandsindikator, das Haushalts-pro-Kopf-Einkommen oder die Haushalts-pro-Kopf-Konsumausgaben).

Die Ergebnisse des dritten Forschungsthemas (3) „Einfluss der Ressourcenkapitalausstattung und des Ressourcenkapitalertrags auf die Produktivitätsunterschiede im Maisanbau zwischen

Haushalten mit unterschiedlichem Wohlstandsniveau“ zeigen, dass die quantitativen Unterschiede im Ressourcenkapital der Haushalte bedeutender für die Höhe der Abstände im Maiseinkommen pro Hektar zwischen dem ärmsten Drittel und den wohlhabenderen Haushalten sind als die Unterschiede im Ertrag des Ressourcenkapitals. Die quantitativen Unterschiede im Ressourcenkapital der Haushalte tragen dabei signifikant zu mehr als zwei-Drittel des Gesamtabstandes im Maiseinkommen bei, während Unterschiede im Ertrag des Ressourcenkapitals keinen eigenständigen signifikanten Beitrag leisten. Zum quantitativen Einfluss des Ressourcenkapitals tragen die Kreditobergrenze der Haushalte, die ethnische Zugehörigkeit des Haushaltsvorstands und der Landwert der Hochlandfelder große und signifikante Effekte bei. Die Größe der kultivierten Fläche, der Gesamtwert von Büffeln und Rindern und das Alter des Haushaltsvorstands haben kleinere und weniger konstante Effekte. Die Kreditobergrenze ist die bedeutendste und konstanteste Antriebsgröße der quantitativen Effekte des Ressourcenkapitals, was zeigt, dass finanzieller Zugang nach wie vor ein entscheidendes Hindernis für die landwirtschaftliche Produktivität von armen, den ethnischen Minderheiten zugehörigen Haushalten ist. Die ethnische Zugehörigkeit des Haushaltsvorstands hat einen starken und positiven, aber rückläufigen Einfluss auf die Höhe der Maiseinkommensabstände, was darauf hinweist, dass den für ethnische Gruppen wichtigen weichen Faktoren wie Unterschiede im Standort, den landwirtschaftlichen Praktiken und Traditionen mehr Beachtung geschenkt werden sollte. Von der Signifikanz des Landwerts der Hochlandfelder schlussfolgern wir, dass umweltbedingte Faktoren wie die Verhinderung von Bodenerosion, dem Schutz der Bodenfruchtbarkeit und die Berücksichtigung langfristiger Nachhaltigkeit stärkere Betonung erfahren sollten. Weitere untergeordnete Faktoren, welche die Maiseinkommensabstände beeinflussen, werden in der Dissertation in größerem Detail diskutiert.

Ausgehend von den Ergebnissen der Dissertation ziehen wir die folgenden wesentlichen Schlussfolgerungen für die Entwicklung von armutsmindernden Strategien zur Verbesserung der landwirtschaftlichen Produktivität in Hochlandagrarsystemen.

Erstens, die landwirtschaftliche Forschung und Beratung sollte darauf achten, Engpässe zu identifizieren, denen Haushalte aufgrund ihres Wohlstandsniveaus ausgesetzt sind, um zu verhindern, dass die spezifischen Hindernisse, mit denen ärmere und wohlhabendere Landwirte konfrontiert sind, dazu führen können, dass langfristige Armutsfallen, eine erhöhte Ineffizienz sowie die Verschwendung von Ressourcen gefördert werden. Aus diesem Grund wird eine Forschung und Beratung benötigt, welche eine stärkere Betonung auf die Integration von wohlstandsabhängigen agronomischen, ökonomischen und risikobasierten Aspekten legt, den effizienten Einsatz von Betriebsmitteln stärker berücksichtigt und einen stärkeren Schwerpunkt auf die Anpassung technologischer Innovationen an die Gegebenheiten und Bedürfnisse der Agrarsysteme von ethnischen Minderheiten in Bergregionen legt.

Zweitens, eine stärkere Betonung sollte daraufgelegt werden, armen Haushalten dabei zu helfen, mit Risiken zurechtzukommen. Während alle Haushalte Ertrags-, Betriebsmittelpreisund Verkaufspreisrisiken ausgesetzt sind, beeinflusst die Risikoaversion Entscheidungen über die Intensivierung des Betriebsmitteleinsatzes in Haushalten des ärmsten Drittels. Deswegen sollte im Besonderen für die Ärmsten ein größeres Gewicht daraufgelegt werden, Risikomanagementmöglichkeiten auszuweiten, welche der geringeren Risikowiderstandsfähigkeit und der höheren Risikoaversion der Armen sowie den oft höheren Transaktionskosten Rechnung tragen. Dies beinhaltet Maßnahmen zur Erhöhung der Finanzkompetenz von Haushalten, die Ausweitung von Möglichkeiten Konsumkredite aufzunehmen, die Vernetzung von Krediten mit Versicherungs- und Sparoptionen, die Reduktion von Transaktionskosten und Hindernissen, welche einer erfolgreichen Kreditaufnahme entgegenarbeiten, sowie, wenn möglich, die Entwicklung von Innovationen wie die Verbesserung von Saatgut oder landwirtschaftlichen Managementsystemen, welche die Kapazität haben, die Verlustrisiken der landwirtschaftlichen Produktion zu senken.

Drittens, die Ausstattung mit Ressourcenkapital sollte als eine wichtige Antriebsgröße für Unterschiede in der landwirtschaftlichen Produktivität zwischen armen und wohlhabenderen Landwirten betrachtet werden. Von den Ergebnissen, dass die quantitativen Unterschiede im Ressourcenkapital der Haushalte die wesentliche und einzig signifikante Antriebsgröße für Abstände in der Maisproduktivität zwischen armen und wohlhabenderen Landwirten sind, schließen wir, dass die Ärmsten das gleiche landwirtschaftliche Produktionspotenzial haben können wie wohlhabendere Haushalte, wenn sie das gleiche Niveau an Ressourcenkapital zur Verfügung hätten. Haushalte dabei zu unterstützen, dass sie Zugang zu Ressourcen haben und Ressourcen akkumulieren können, sollte deswegen ein wichtiges politisches Ziel sein. Dies ist im Besonderen zutreffend für Ressourcen, welche durch die Agrarforschung, eine verbesserte Agrarberatung und eine zielgerichtete Entwicklungspolitik beeinflussbar sind. Auf Grundlage unserer Forschungsergebnisse betrifft dies die Verbesserung des Kreditzugangs, die Unterstützung ethnischer Minderheiten und Anstrengungen, welche die Nachhaltigkeit der Hochlandagrarsysteme verbessern.

Viertens, Investitionen in die langfristige Nachhaltigkeit des Maisanbaus und der Hochlandagrarsysteme werden empfohlen. Obwohl Mais kurzfristig eine sehr profitable Marktfeldfrucht sein kann, zeigen die Ergebnisse dieser Dissertation auch, dass eine starke Spezialisierung des Maisanbaus zu vielfachen kurzfristigen und langfristigen ökonomischen wie nachhaltigkeitsbedingten Existenzrisiken führen kann. Dies beinhaltet auch eine möglicherweise begrenzte Profitabilität von zusätzlichem Kredit und Betriebsmitteln sowie eine starke Abhängigkeit der Haushalte von der Qualität der natürlichen Ressourcen. Maßnahmen sollten sich deswegen sowohl auf die direkte Verbesserung der Bedingungen für die Maisproduktivität als auch auf die Verbesserung der Bedingungen für eine langfristige Entwicklung richten. Solche Maßnahmen sollten Haushalte dabei unterstützen, stärker in profitable landwirtschaftliche und außerlandwirtschaftliche Diversifizierung zu investieren, die Infrastruktur und die Agrarberatung verbessern, um die Profitabilität von ungenutzten Feldfruchtalternativen zu erhöhen, sowie die Entwicklung von profitablen Bodenschutzmaßnahmen und Investitionen in Bildung und in außerlandwirtschaftlichen Beschäftigungsmöglichkeiten unterstützen.

List of Figures

Figure 1-1: Poverty rates in Vietnam by residence (1998-2016) 2
Figure 1-2: Adoption of modern technologies by world region 6
Figure 1-3: Maize production in Vietnam 2007 14
Figure 2-1: Maize share, maize yield, share of agricultural income, and poverty rate in Vietnam by province 18
Figure 2-2: Household pathways of intensification 20
Figure 3-1: Frequency distribution of farmers' wealth based on three different measures of wealth 59
Figure 3-2: Marginal effect of risk aversion across different wealth levels of farmers 65
Figure 3-3: Marginal effect of risk aversion across different wealth levels of farmers using various measures of fertiliser use intensity 66
Figure 3-4: Marginal effect of risk aversion across different wealth levels of farmers using various measures of wealth 67
Figure 4-1: Conceptual framework to analyse the impact of household assets 70

List of Tables

Table 2-1: Means tests used for statistical analysis of descriptives 21
Table 2-2: Overview of the total sample and the regression/decomposition sample by year 22
Table 2-3: Overview of ethnicity, agricultural system, and maize production by household wealth tercile and year[1,2,3] 25
Table 2-4: Maize variety grown by household wealth tercile 2007-2010[1] 28
Table 2-5: Maize seed input by household wealth tercile 2007-2010............................... 31
Table 2-6: Maize seed input prices separated by seed variety, payment type, and wealth tercile 2008-2010 32
Table 2-7: Fertiliser utilization by wealth tercile 2007-2010[1] 36
Table 2-8: Fertiliser input by wealth tercile 2007-2010[1]... 37
Table 2-9: Fertiliser prices by fertiliser type, payment type, and wealth tercile 2008-2010[1,2,3]... 38
Table 2-10: Maize output by wealth tercile 2007-2010.. 43
Table 2-11: Maize output prices by variety and wealth tercile 2007-2010 44
Table 3-1: Final list of indicators in the wealth index 59
Table 3-2: Description of variables... 61
Table 3-3: Selected regression outputs for fertiliser use intensity of all maize farmers 64
Table 4-1: Descriptives of variables included in regression and decomposition models 79
Table 4-2: Regression results – All households.. 86
Table 4-3: Regression results – Poor households 87
Table 4-4: Regression results – Non-Poor households 88
Table 4-5: Summary Oaxaca-Blinder decomposition results 90
Table 4-6: Detailed Oaxaca-Blinder decomposition results 2007...................................... 96
Table 4-7: Detailed Oaxaca-Blinder decomposition results 2008...................................... 97
Table 4-8: Detailed Oaxaca-Blinder decomposition results 2009...................................... 98
Table 4-9: Detailed Oaxaca-Blinder decomposition results 2010...................................... 99

Table A-1: Results of the selection model (Tobit regression) 124

Abbreviations

ANOVA	Analysis of Variance
CPI	Consumer Price Index
GDP	Gross Domestic Product
GSO	General Statistical Office (of Vietnam)
GSO-WB	General Statistical Office and The World Bank
ha	Hectare(s)
HH	Household(s)
kg	Kilogram(s)
log	Natural Logarithm
LURC	Long-term Use Rights Certificates (also referred to as Red Book)
masl	Metres above Sea Level
m^2	Square metre(s)
MV	Improved Seed Variety
NMM	Northern Midlands and Mountains
NPK	Nitrogen, Phosphorous, Potassium fertiliser
OB / OBD	Oaxaca-Blinder Decomposition
OLS	Ordinary Least Square
PCA	Principal Component Analysis
PPP	Purchasing Power Parity
SD	Standard Deviation
t	Ton(s)
USD	U.S. Dollar
VND	Vietnamese Dong
yrs	Years

The currency in Vietnam is the Vietnamese Dong (VND). 1 USD is equal to 7528.385 VND in 2011 purchasing power parity (PPP) based on the conversion factor for private consumption (The World Bank, 2020).

1. Introduction

1.1. Problem setting

Upland systems in South East Asia are undergoing tremendous changes. Driven by population growth, increased access to infrastructure and markets, policy reforms, new technologies, and economic growth, farming systems in the uplands increasingly follow the pathway from traditional near subsistence agriculture towards intensification, commercialization, and integration with the wider global economy (Kono and Rambo, 2004; Schreinemachers et al., 2013). Independent of these recent developments, upland areas remain among the poorest of the world, plagued by high levels of poverty, food insecurity, low levels of agricultural productivity, increasing environmental degradation, poor infrastructure, and social and political marginalization (Akramov et al., 2010; Kono and Rambo, 2004; Schreinemachers et al., 2013). In consequence, research and policy are needed that support sustainable agricultural intensification and diversification, the development of adapted technologies, improvements in rural institutions and service provision, that help people manage risks, protect the natural resource base from degradation, and emphasize the needs of the resource constraint and economic and social marginalized, such as the poor and ethnic minorities.

In Vietnam, agricultural and economic development was strongly driven by the economic, institutional, and policy reforms of Doi Moi (renovation) that transformed the country from a centrally planned to a state-regulated market-orientated economy since the late 1980s. Agriculture changed from a cooperative and state farm production system (1960-1988) to a system with farmers as the main decision-makers (Saint-Macary, 2014; Thanh et al., 2004). Reforms in the agricultural sector included the transfer of land use rights to households[1], the successive liberalization of agricultural input and output markets, the reduction of barriers to domestic and international agricultural trade, and the decline in crop choice restrictions (Brandt and Benjamin, 2002; Glewwe, 2004; Saint-Macary, 2014). These reforms resulted in a substantial increase in agricultural prices, lower input prices, higher input use, higher yields, stronger agricultural commercialization, higher land productivity, and increased agricultural diversification (Brandt and Benjamin, 2002; Kompas et al., 2012; Minot et al., 2006; Pingali and Xuan, 1992)[2]. Vietnam also turned from a net rice importer in the 1980s into a major net exporter of rice (third largest global exporter since 1993 with 3.0 (1996), 4.6 (2006), and 5.2

---

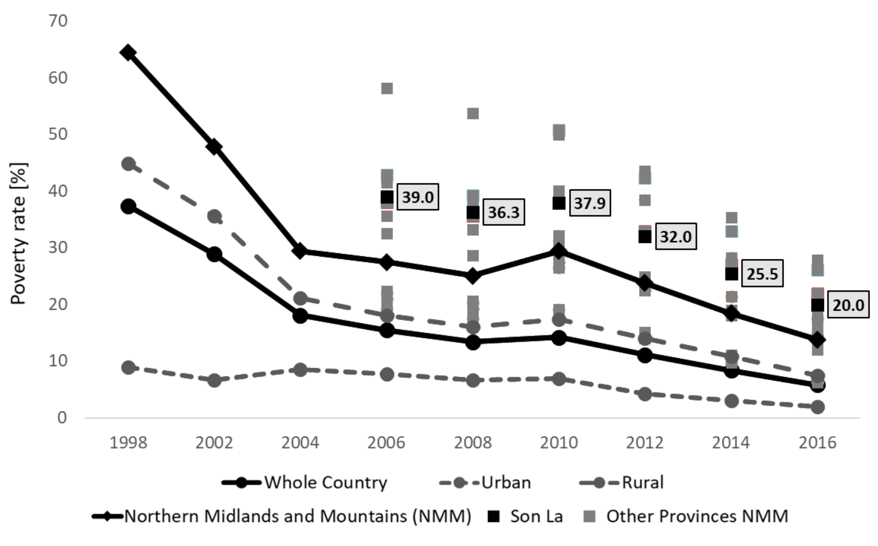
[1] While the land stays in the ownership of the state, the 1993 land law granted users with five rights: the right to exchange, transfer, mortgage, inherit, and lease out the land. Use rights in the form of land use certificates are issued by 20 years for annual crop land, for 50 years for perennial crop land, and an unlimited time period for residential land (Saint-Macary, 2014: 12).

[2] Rice production output, which is Vietnam's main staple crop, increased from 260 kg per person (2.6 tons per hectare) in 1986, to 361 kg per person (3.8 tons per hectare) in 1996, to 430 kg per person (4.9 tons per hectare) in 2006, to 466 kg per person (5.6 tons per hectare) in 2016 (GSO, 2020; Pingali and Xuan, 1992).

(2016) million tons of net export), coffee (second largest global exporter since the late 1990s with 0.28 (1996), 0.98 (2006), and 1.40 (2016) million tons of net export), as well as an exporter of seafood, fruits, and vegetables (Doutriaux et al., 2008; FAOSTAT, 2020; Glewwe, 2004; Minot et al., 2006). Per-capita GDP (average annual growth rate) [in constant 2010 USD] increased from 310 USD in 1980 to 424 USD (3.2%) in 1990, to 748 USD (5.8%) in 2000, to 1,310 USD (5.8%) in 2010, to 1,735 USD (4.8%) in 2016 (FAOSTAT, 2020). In the same period, the 1.9 USD (3.2 USD) poverty headcount (per person per day, PPP-adjusted 2011) dropped from 52% (80%) in 1992, to 37% (70%) in 2002, to 19% (51%) in 2006, to 2% (8%) in 2016 (Andrés et al., 2019; PovcalNet, 2020).

Notwithstanding the productivity improvements in the agricultural sector, the increasing rural incomes and living standards, and the broad-based economic growth, growth in incomes and poverty reduction have not been equal throughout the country. Poverty has become increasingly concentrated in rural areas, poor districts, Vietnam's uplands, and among farming households and ethnic minorities (Glewwe et al., 2002; The World Bank, 2012). This is particularly true for the Northern midlands and mountains (Northern Uplands) in Vietnam, where independent of great successes in poverty reduction, poverty rates remain substantially above average national and rural levels (Figure 1-1).

Figure 1-1: Poverty rates in Vietnam by residence (1998-2016)



Note: Poverty rates as published by the General Statistical Office of Vietnam (GSO, 2020).

The GSO-WB expenditure poverty lines are evaluated for urban (and rural areas) at VND/month/capita 260,000 (200,000) from 1998-2008, 500,000 (400,000) from 2010-2012, 750,000 (605,000) in 2014, and 780,000 (630,000) in 2016. Measured at 2011 purchasing power parity (PPP) this corresponds to poverty lines evaluated for urban (and rural areas) at USD/day/capita in 2011 PPP 1.15 (0.89) from 1998-2008, 2.21 (1.77) from 2010-2012, 3.12 (2.52) in 2014, and 3.37 (2.72) in 2016 (GSO, 2020; The World Bank, 2012, 2020).

Source: Own depiction based on GSO (2020), The World Bank (2012, 2020)

Based on the national (GSO-WB) poverty lines in 2006, the average poverty rate in the Northern Uplands was with 27.5% still roughly twice as high as the national average of 15.5% and roughly one and a half as high as the rural average of 18.0% (GSO, 2020). Within the

Northern Uplands, the 2006 provincial poverty rates ranged between 18.6-58.2% (median 32.5%) (GSO, 2020) with provinces being more remote, less accessible, and having large amounts of sloping terrain, poor soils, and barren land reaching the highest incidences of poverty (Minot et al., 2003). Compared to entire Vietnam in 2006, the Northern Uplands remained the poorest region with eight of its fourteen provinces among the ten poorest provinces in the country (GSO, 2020)[3]. Moreover, while incomes, poverty levels, and food security have been improving also in the Northern Uplands, parts of the Northern Uplands remain with the highest countrywide incidence of food insecurity. While the average national (rural) incidence of food poverty[4] of the population was 6.7% (8.7%), the northwest (northeast) region of the Northern Uplands recorded numbers as high as 29.9% (9.5%) in 2006 (Nguyen, 2011)[5].

Geographically, the Northern Uplands covers approximately 103 000 km², about one-third of the country's area, covering fifteen provinces and more than 2,000 communes, inhabiting about 12.1 million people, constituting 14.3% of Vietnams population in 2006 (GSO, 2006; Tran, 2003). The Northern Uplands are among Vietnam's most ethnically diverse regions, home to more than 30 of 54 Vietnam's officially recognized ethnic groups, which make up 54.7% of the Northern Uplands' population and over half of the ethnic minority population of the country (the overall share of ethnic minorities in Vietnam is 14.3%) (GSO, 2006; Tran, 2003). The terrain is hilly to mountainous with flat valleys in between, containing several mountain ranges and intermontane basins, with elevation levels from 700 to more than 2,000 masl in the northwest to average elevations from 400 to 500 masl in the northeastern regions (Thanh et al., 2004; Tran, 2003). Given the varied and fractured topography and ethnic diversity, the Northern Uplands inherit a wide range of ecological and agricultural systems (Tran, 2003). Altitude differences in farming systems are often high, slopes are often steep, soils are often poor and rocky, and the area of flat land is limited (in some areas as low as 25% of total area) (Minot et al., 2003, 2006). Agriculture is therefore very much dominated by upland cultivation, with crops such as upland rice, cassava, sweet potato, mung bean, and maize grown for food consumption, and maize, tea, fruits, sugarcane, peanuts, soybeans, tobacco, cinnamon, cardamom, anise grown for cash income, while paddy rice, the main staple in Vietnam, can only be cultivated in the valleys or on terraces (Fatoux et al., 2002; Henin, 2002; Keil et al., 2013; Ufer, 2010). In consequence, household rice self-sufficiency is often low and below subsistence needs, while at the same time important for food security,

---

[3] The other two poorest (out of ten) provinces not located in the Northern Uplands in 2006 (poverty rate, #rank): Ha Tinh province, North Central Coast (31.5%, #9); Kon Tum province, Central Highlands (31.2%, #10) (GSO, 2020).

[4] Food poverty in this context means the share of population that fall below a monetary food poverty line which is equivalent to the expenditure level that allows for nutritional needs equivalent to 2,100 calories per day (Nguyen, 2011).

[5] Regions that also reported high food poverty incidence (above 10%) were the Central Highlands (16.4%) and the North Central Coast (14.3%). All other regions had a food poverty incidence below 5% in 2006 (Nguyen, 2011).

especially for poor households with low incomes (Fatoux et al., 2002; Ufer, 2010). Agricultural systems in the Northern Uplands can have nevertheless a high degree of specialization as is the case of maize production in cultivated area in Hoa Binh (60.5%), Son La (47.5%), Cao Bang (44.6%), Bac Kan (42.7%), and Lai Chau (23.0%) provinces (GSO, 2007). Consequently, households can be very dependent on a few income sources for their living.

The privatization of land use rights, the new market opportunities, population growth, the improvements of roads, and the promotion of hybrid seeds and fertilisers by government programs led to stronger intensification, commercialization, and diversification of agriculture also in the Northern Uplands (Keil et al., 2013; Minot et al., 2006; Schreinemachers et al., 2013). Independent of the government support, road improvements, and the strong agricultural commercialization in the past two decades, the Northern Uplands remain relatively poor in terms of infrastructure, human capital, asset levels, and access to public services, such as credit and extension (Minot et al., 2003, 2006; Saint-Macary, 2014; Staal et al., 2014). Moreover, rice and average productivity increases in agriculture in the North have been lower than in the South of Vietnam in the past two decades (JICA, 2013; Kompas et al., 2012). While some of these regional productivity differences may be due to agroecological reasons, a study by Yen et al. (2013) finds that many crops in the Northern Uplands show large productivity gaps under current farming practices compared to recommended technology (37% hybrid spring rice, 41% hybrid summer rice, 32% upland rice, 34% hybrid maize, 31% soybean). At the same time, intensification and diversification of farming systems require higher investments, households' asset base have become more important for household production and incomes, and market risks have grown (Sadoulet et al., 2002; Sikor and Vi, 2005). In consequence, differentiation between households in the Northern Uplands compared to the pre-reform period has increased (Sadoulet et al., 2002; Sikor and Vi, 2005). The level of natural, human, financial, social, and other capitals that may be needed to successfully intensify and diversify agricultural production may particularly put poor households at a disadvantage since they have a lower asset base and are less able to cope with household risks (Dercon and Christiaensen, 2011; Tuyen, 2015). At the same time, the poorer households in the Northern Uplands and Vietnam still depend the most on agricultural income (Minot et al., 2006; The World Bank, 2012). Negative effects of low levels of human capital, low asset endowments, and high level of risk aversion on agricultural productivity may therefore be particularly pronounced in the input-intensive, highly specialized, and highly commercialized maize farming systems. Studies that quantitatively analyse the extent and the sources of agricultural intensification and productivity differences of maize production for households in the Northern Uplands and Vietnam are however very limited (Lançon et al., 2014; To-The and Nguyen-Anh, 2021; Yen et al., 2013). In particular, these studies do not differentiate explicitly how differences in risk aversion and asset levels between households of different wealth contribute to differences in agricultural intensification and productivity. For this reason, this doctoral thesis seeks to fill these research gaps by analysing (1) the level and short-term changes in agricultural input use and productivity in maize production by household wealth, (2) the impact of risk aversion on fertiliser use in maize production by household wealth, and (3) the impact of household asset levels and the return to assets on productivity differences in maize production between households of different wealth.

1.2. Research focus

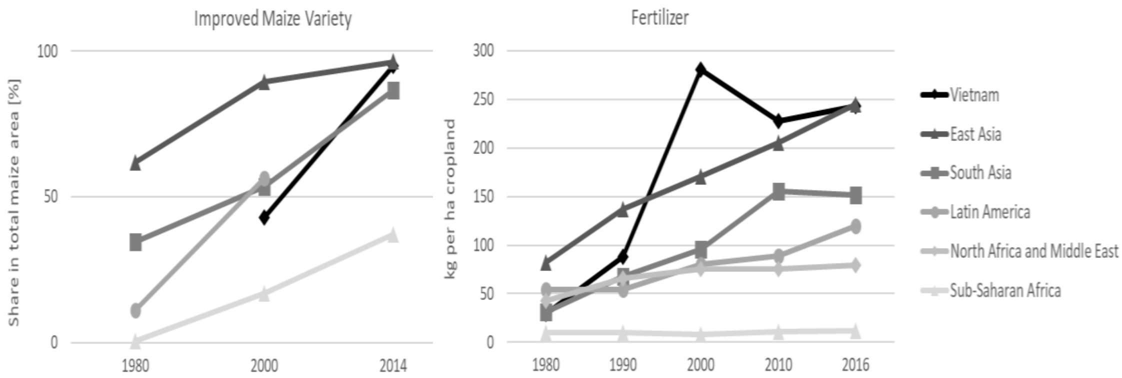
1.2.1. The importance of technology adoption for agricultural productivity growth

Efforts to increase agricultural output, productivity, and incomes to improve food security and reduce poverty among smallholder farmers by supporting the adoption of modern high yielding seed varieties, synthetic fertilisers, and improved management practices have been a major focus of agricultural development research since the green revolution of the 1960s (Hazell, 2009; Pingali, 2014). Still raising agricultural productivity growth remains crucial for several reasons. (1) In most low-income countries the agricultural sector is still an important contributor to national GDP and employment: of 5.5 billion people that live in developing countries, 3 billion live in rural areas, and three-quarters of the extreme poor living in developing countries are farming households (Dethier and Effenberger, 2012). Moreover, even in transforming countries with a falling share of GDP in agriculture, agriculture remains crucial for many people (Dethier and Effenberger, 2012). (2) Improvements in agricultural productivity tend to have a higher impact on poverty reduction and income growth of the poor than productivity improvements in other sectors: So find Ivanic & Martin (2018, cited from Fuglie et al., 2020) that GDP growth originating in agriculture has about twice the impact on reducing extreme poverty as a comparable productivity increase in industry or service.[6] (3) Agricultural productivity will have to come increasingly from improved total factor productivity growth: options to use the expansion of land for agricultural productivity growth are more and more limited, especially in populous regions of the world as in Vietnam. Agriculture will have to feed 9 billion people in 2050 with the highest numbers of increase in countries that suffer already from resource degradation and hunger, while at the same time the demand for food and fibre is expected to rise so that additional agricultural growth will have to come from technologies that allow more efficient resource use (FAO, 2012; Fuglie et al., 2020; Nguyen, 2017). (4) Technology adoption at the household level like improved seeds and fertilisers has shown to have a positive impact on yields (Akossou et al., 2016; Smith, 2008), crop income (Gebremedhin et al., 2009; Khonje et al., 2015; Smith, 2008), consumption expenditure (Khonje et al., 2015), and food security (Asfaw et al., 2012; Khonje et al., 2015). (5) Moreover, agriculture is profitable. Latest studies have found that hourly wages in food production can compete or accelerate wages derived from non-farm income in rural areas (Fuglie et al., 2020).

[6] The study by Ivanic and Martin (2018) defines extreme poverty as household living below 1.25 USD/person/day.

Independent of the need for higher technology adoption to raise the overall productivity of agriculture and hence household incomes, technology adoption in many developing countries remains low and unevenly distributed (Figure 1-2).

Figure 1-2: Adoption of modern technologies by world region



Source: Own depiction based on CIMMYT (2017), FAO (1999), Fuglie et al. (2019), Maredia et al. (2017), USDA-ERS (2019)

Regional developments have been very different, with the lowest level of technology adoption in SSA and higher levels in Asia and Latin America. Nevertheless, while these studies show general trends, adoption rates may be high, but adoption intensities may still be low (Mugisha and Diiro, 2010), and adoption levels may substantially vary between regions within countries, such as lowland and upland areas (Maredia et al., 2017; Pingali, 2014). This doctoral thesis focuses therefore on factors that affect technology adoption, intensification, and agricultural productivity on a more detailed level for poor and non-poor farmers in the Northern Uplands of Vietnam.

1.2.2. Factors affecting technology adoption

When technology adoption is so important for agricultural productivity, why do adoption rates or adoption levels of agricultural technologies differ between regions and households? To answer these questions, context, institutional, and household level based factors can be considered as well as the risks that are embodied in adopting new technologies.

In the following, this chapter gives a literature review that summarizes the main institutional and household level factors that can contribute to differences in adoption rates and levels between households in more detail.

a) Research and development (R & D) environment

For smallholder households to adopt agricultural technologies, suitable agricultural technologies that are agroecological, technical, and economical feasible have to be available and disseminated (Lunduka et al., 2012). The availability of suitable technologies for smallholder farmers is thereby directly linked to the priority setting and investments of international and national research systems as well as private enterprises (Fuglie et al., 2020). Investments into R & D can be justified by their large rates of returns. For example, Alston et al. (2000: 58) reviewing 292[7] papers on the returns to agricultural R & D, including both studies on research and extension from the years 1958 to 1998, find a median of the internal rate of return of 44.0% for all agriculture, 43.6% for all field crops, 47.3% for maize, 40.0% for wheat, 51.3% for rice, 53.0% for livestock, 33.3% for tree crops, 16.5% for resource-related topics, and 13.6% for forestry R & D, respectively. [8] Research further shows that countries with higher public spending per agricultural worker (which includes also spending on extension, subsidies, and other agricultural support programs) reach higher levels of food security and suffer less from undernutrition (FAO, 2012). Investments in public research systems are further crucial because public investment in agriculture promotes additional private investment in the sector (FAO, 2012).

b) Access to information

Information can be viewed as a “productive farm input” into technology adoption and farm management like other productive inputs, such as land, labour, and other human, physical, and financial capitals (Anderson and Feder, 2007: 2348). Information raises the familiarity with technology, ensures efficient technology use, and hence increases the returns to and decreases the risk of using technologies, which in turn supports technology adoption. So find Foster and Rosenzweig (1995) that in India profitability of adopting improved seed varieties increased with experience, while it was unprofitable at first in the presence of completely inexperienced farmers with no experienced neighbours. Zhao et al. (2016) find that farmer training programs can increase the profitability, nitrogen-use efficiency, and adoption of improved seeds, management practices, and fertilisers. Information can thereby be delivered by public and private extension channels or through semiformal or informal social networks, such as rural groups, friends, neighbours, and relatives (Anderson and Feder, 2007; Beyene and Kassie, 2015; Birner et al., 2009; Foster and Rosenzweig, 1995; Krishnan and Patnam, 2014; Matuschke and Qaim, 2009). So find Krishnan and Patnam (2014) that extension access is important in the early phases of adoption, while learning from social networks becomes more important later on. Moreover, access to information channels varies often with wealth and remoteness (Alene et al., 2008). Informal learning may be particularly important for the

---

[7] The full sample includes 292 studies of which 283 were used for the papers analysis. The here mentioned results are based on the sample of 283 studies that include overall 1,852 valid observations (Alston et al., 2000: 55).

[8] Rate of return can be real or nominal, ex-ante or ex-post, average or marginal, private or social, or the benefit-cost ratio depending on the underlying study (Alston et al., 2000: 56).

poor that often have lower access to information as well as can tolerate less self-experimentation with new technologies than the wealthier farmers (Foster and Rosenzweig, 1995).

c) Access to natural capital

Natural resources include the access to land, the quality of land, the access to water as well as access to other natural resources, such as biodiversity or any other "natural resource stock from which resource flows and services (e.g. nutrient cycling, erosion protection) [that are] useful for livelihoods [can be] derived" (DFID, 1999: 2.3.3). Access to land affects technology adoption through several channels, such as the availability of land for cultivation, the interaction between land size and risk (Just and Zilberman, 1983), the quality of land (Beyene and Kassie, 2015; Marenya and Barrett, 2009a, 2009b), and the value of land as collateral for accessing loans (Saint-Macary, 2014). Availability of land can have a positive or negative impact on technology adoption depending on whether its function within households' livelihood strategies is related to intensification or extensification. For example, if larger land size mitigates the risks associated with adopting a new risk increasing technology then land size can have a positive impact on technology adoption (Just and Zilberman, 1983)[9], or when land can be used as collateral for loans for investments, or the technology to be adopted is not divisible below a certain threshold (David, 1969 cited from Sunding & Zilberman 2001). The abundance of land however can also rather support the extensification of land use instead because households with less land are often forced to cultivate their land more intensively than households with more abundant land in order to make a living. It further may be easier to apply a larger amount of fertiliser to smaller plots of land if capital, labour, or draft power is constraint and mechanization is not affordable or feasible (Simtowe et al., 2011; Wubeneh and Sanders, 2006). Technology adoption is further positively related to natural factors that increase the return to these technologies, such as the relationship between soil fertility and modern seed and fertiliser application (Beyene and Kassie, 2015; Marenya and Barrett, 2009b), or irrigation access that increases the returns and decreases the risks of yield variations and hence reduces possible losses (Thulstrup, 2015).

d) Property rights

Property rights in the form of titled land rights or tenure security can increase the demand for investments, increase access to capital through the availability of collateral, enhance management efforts and hence increase technology adoption and agricultural productivity (Deininger and Feder, 2001; Nguyen et al., 2016). For example, property rights can increase credit access in formal markets (Saint-Macary, 2014), the amount of loans households take out for agricultural production (Nguyen, 2019), the use of high yielding varieties (Nguyen,

[9] Given that relative risk aversion is increasing and absolute risk is decreasing and the correlation of yields under the old and new technology is low or negative (Just and Zilberman, 1983).

2019), the use of fertiliser and manure inputs (Nguyen, 2012; Nguyen et al., 2016), and increase agricultural productivity (Nguyen, 2012).

e) Access to physical capital

Access to additional physical capital mainly concerns additional inputs, farm equipment, and draft power. Additional inputs are often complementary and can raise the productivity of adopting a new technology. For example, livestock and supplemental farm equipment can support the timely preparation of land, increase the productivity of agricultural activities and therefore support the adoption rates of seeds and fertilisers (Alene et al., 2008; Foster and Rosenzweig, 1995; Smith, 2008).

f) Access to input and output markets

Rural infrastructure, such as the availability of (all-weather) roads, markets, traders, or input dissemination boards, influences the adoption of agricultural technologies. For once, rural infrastructure allows to purchase inputs and sell outputs, but also because rural infrastructure directly influences the profitability of the agricultural activities. Remoteness, both in distance and travel time, i.e. through bad quality streets, does not only decrease accessibility but also increases transaction costs. As a consequence, input prices become relatively more expensive and output prices relatively decrease (Damania et al., 2017; Thanh et al., 2004; Thulstrup, 2015). This not only decreases the profitability of input use to farmers but also may have a negative impact on technology adoption, yield levels, and the overall rate of commercialization of agricultural production (Alther et al., 2002; Damania et al., 2017; Lançon et al., 2014). While access to roads and markets are direct measures, other infrastructure-related variables, such as the number of available traders (Beyene and Kassie, 2015), the ownership of transport equipment (Alene et al., 2008; Damania et al., 2017; Lançon et al., 2014), and the participation in group marketing (Alene et al., 2008), can improve technology adoption, too. Moreover, better accessibility also contributes to better extension access, better access to market information and government projects, more opportunities for off-farm employment, stronger social networks outside the village, and better education possibilities, which in turn support the intensification of agriculture and the adoption of technologies (Alther et al., 2002).

g) Human capital

Human capital variables include age, gender, education level, labour availability, dependency ratio, and individual factors, such as risk aversion or entrepreneurial capacities of the farmer. They are important because they influence the access to other assets that determine technology adoption, determine the return to technology adoption, and influence how farmers handle risks. Human capital variables that are often positively related to technology adoption are education (Beyene and Kassie, 2015), household size, and labour availability (Beyene and Kassie, 2015; Thulstrup, 2015) because they either increase the familiarity with technologies and/or raise the productivity of using inputs. Human capital variables that are often negatively related to technology adoption are high dependency ratio because it can force households to favour food over cash crop production and to take lower risks (Thulstrup, 2015) as well as gender, i.e. being female, because women often have lower access to assets, such as good fertility land, bigger plots, inputs, and extension, which leads to lower opportunities or profitability to adopt modern technologies (Fisher and Carr, 2015; Kilic et al., 2015). Age, on the other hand, is linked to both risk aversion and experience, which can influence the extent and returns to technology adoption in opposite directions. While old age and experience are generally related to higher returns from technology adoption, they are also related to lower risk-seeking and lower adoption of technologies. Hence, often a quadratic impact of age on technology adoption is found (Beyene and Kassie, 2015).

h) Access to financial capital

Financial capital includes all forms of credit, off-farm income, savings, assets, and insurance. Households need financial capital as a way to finance productive investment as well as to insure themselves against consumption risks associated with production risks. However, the level of assets and own financial resources, as well as the depth and access to formal financial institutions in low-income countries, are very low (Čihák et al., 2012; Demirgüç-Kunt and Klapper, 2012; Zeller et al., 1997). In consequence, households often face liquidity constraints for investments, have low risk-bearing ability, and limited means to protect themselves from production shocks and to smooth consumption (Dercon, 2002; Dercon and Christiaensen, 2011; Zeller et al., 1997). To overcome these liquidity constraints, access to formal and informal credit sources as well as off-farm employment is crucial (Stampini and Davis, 2009; Zeller et al., 1997). However, access to formal credit is often extremely low, especially for the rural poor, and often connected to the availability of collateral so that many households have to resort to informal credit sources with higher interest rates (Ali et al., 2014; Saint-Macary, 2014; Zeller et al., 1997). Poorer households face more often credit constraints or take less often out loans (Ali et al., 2014; Saint-Macary, 2014; Simtowe et al., 2009), borrow lower amounts in formal, informal, and semi-informal credit markets (Ali et al., 2014; Saint-Macary, 2014), and face higher interest rates (Saint-Macary, 2014), while the non-poor additionally have more opportunities to self-finance (Simtowe et al., 2009). Households that are credit constrained are found to use less often and lower amounts of improved seed, chemical fertiliser, and pesticides (Ali et al., 2014; Dercon and Christiaensen, 2011; Simtowe et al., 2009).

i) Access to social capital

While many definitions of social capital exist (DFID, 1999; Grootaert, 1998), a way to define social capital is the "social resources upon which people draw in pursuit of their livelihood objectives" such as informal and formal "relationships, networks, and group memberships" including "trust and reciprocity" (DFID, 1999: 2.3.2). Regarding technology adoption, social capital is important because it can have an indirect or direct positive impact on the uptake of technologies. So do social capital and social networks facilitate access to public services, such as formal credit, health care, education, and agricultural extension (Hoang et al., 2016), support information sharing and learning (Foster and Rosenzweig, 1995; Grootaert, 1998), and increase the risk-bearing capacity of households. Research that links social capital variables directly to technology adoption shows that the share of network members that adopt a technology (Matuschke and Qaim, 2009), membership of an organization or group (Beyene and Kassie, 2015; Matuschke and Qaim, 2009), the number of relatives present in the village (Beyene and Kassie, 2015) can all have a positive impact on technology adoption. Moreover, studies also show that social capital not only can influence the uptake of technologies but can have a positive impact on the building up of assets (Quisumbing and Kumar, 2011).

j) Risk and risk management

Risk and uncertainty are important features of agriculture production. Many sources of economic writing distinguish between risk and uncertainty. While risk is often defined as "imperfect knowledge where the probabilities of the possible outcomes are known, and uncertainty exists when these probabilities are not known" (Hardaker et al., 2015: 4), it is also possible to define "uncertainty as imperfect knowledge and risk as uncertain consequences, particularly possible exposure to unfavourable consequences. […] To take a risk, then, is to expose oneself to a chance of loss or harm" (Hardaker et al., 2015: 4). This corresponds to the most frequently used concept in agricultural economics to define risk and risk aversion in relation to downside risk, where downside risk is defined as the probability to face an adverse shock, such as low yields, low income, or low consumption. Risk in agriculture can have many sources, such as production risks that originate from unpredictable environmental conditions, like uncertain timing and amount of rainfall, risks of cold spells, or plant and livestock pests and diseases, market-based risks, such as fluctuations in input and output prices or the lack of quality inputs, institutional risks, like changes in government policies and public service provision, as well as personal risks, such as bad health, injury, or death (Hardaker et al., 2015: 5). The importance for households to consider downside risk in their choices about technology and input levels follows households' need to ensure a minimum of basic consumption, especially when households are close to the poverty line (Alderman and Paxson, 1992; Zimmerman and Carter, 2003). Households therefore try to avoid risks that endanger consumption and crucial asset levels and instead opt for low-risk – low-income production modes that have lower income variance but are also less profitable on average. This is particularly true if households are poor and are therefore at particular risk to fall below a certain consumption minimum and when means to smooth consumption through consumption credits, insurance, savings, social networks, or assets are limited (Dercon, 2002; Dercon and Christiaensen, 2011; Rosenzweig and Binswanger, 1993; Zimmerman and Carter, 2003). Consequently, many studies find that low levels of income, the limited option to smooth consumption, and the related risk aversion of farmers translate into a negative impact on technology adoption when the technology to be adopted is risk increasing (Asfaw et al., 2016; Dercon and Christiaensen, 2011). If adopting a technology reduces the downside risk, as in the case of varieties that are resistant to drought or flood, then technology adoption increases among the poor and risk averse (Emerick et al., 2016; Holden and Quiggin, 2017).

1.2.3. Thesis objective, research questions, and hypotheses

In the Northern Uplands of Vietnam, maize constitutes an important, highly specialized, and strongly commercialized upland crop for poor and non-poor farmers alike (Keil et al., 2013; Thanh et al., 2004; Thanh and Neefjes, 2005). Intensification of upland agriculture remains high on Vietnam's policy agenda (Nguyen, 2017). Yet, evidence to quantify actual intensification levels in Vietnam's Northern upland farming systems in general and in maize farming systems in particular are rare. Recent studies on maize production in the Northern Uplands have investigated the rural maize marketing structure (Lançon et al., 2014), the factors that influence household allocation to maize (Keil et al., 2013), the overall tendencies in input use for maize at the provincial level (Nguyen, 2017), the technical efficiency of maize production in terms to yield (To-The and Nguyen-Anh, 2021), and the extent of the maize income gap between actual farmers practice and potential improved agricultural practice (Yen et al., 2013). Important research gaps about technology adoption, maize intensification, and maize productivity gains however remain. In particular, households may face different challenges regarding technology adoption, maize intensification, and maize productivity based on their wealth level. Yet, none of the aforementioned studies differentiates explicitly how differences in asset levels and risk aversion between households of different wealth contribute to differences in agricultural intensification and productivity. This doctoral thesis seeks to fill these research gaps by investigating the following research topics: (1) the level and short-term changes in agricultural input use and productivity in maize production by household wealth, (2) the impact of risk aversion on fertiliser use in maize production by household wealth, and (3) the impact of household asset levels and the return to assets on productivity differences in maize production between households of different wealth. From this analysis, we attempt to find out more details on the maize intensification process in the Northern Uplands in particular and to draw conclusions for upland intensification processes in general.

The research topics of this doctoral thesis include the following research questions and hypotheses.

Research topic 1: Level and short-term changes in agricultural input use and productivity in maize production by household wealth

Research topic 1 is addressed in chapter 2 of the doctoral thesis and includes the following research questions and hypothesis:

a) How do adoption rates of modern inputs, input levels, and agricultural productivity of maize production depend on households' wealth and change over time?

b) Do households of different wealth face systematically different input and output prices and hence differences in economic incentives?

c) To what extent are households of different wealth affected by production risks through yield, input and output price changes?

- Hypothesis 1: Since households of different wealth have different levels of assets available, their ability to invest in agricultural production as well as their agricultural productivity differs. Households of different wealth may also face different input and output prices due to differences in accessibility or other forms of disadvantages. Production risks taken by households of different wealth may diverge since households with more wealth can afford to invest in riskier agricultural strategies than the less wealthy.

Research topic 2: Impact of risk aversion on fertiliser use in maize production by household wealth

Research topic 2 is addressed in chapter 3 of the doctoral thesis and includes the following research questions and hypothesis:

a) Does household's individual risk aversion have a different impact on fertiliser use decisions of households of different wealth?

b) Does the way household wealth is measured matter for the impact of risk aversion on fertiliser use by household wealth?

c) Does the type of fertiliser measure used matter for the impact of risk aversion on fertiliser use by household wealth?

- Hypothesis 2: Since ensuring minimum consumption and protecting vital assets is an important livelihood goal of households (Alderman and Paxson, 1992; Zimmerman and Carter, 2003), individual risk aversion has a larger effect on the fertiliser input decisions of poorer households that are closer to the minimum consumption level than on the fertiliser input decisions of wealthier households that more easily can cover potential shortfalls in crop output by drawing from their stock of wealth. We expect that the effects of risk aversion on fertiliser use by household wealth are independent of the type of wealth and fertiliser measures used.

Research topic 3: Impact of household asset levels and the return to assets on productivity differences in maize production between households of different wealth

Research topic 3 is addressed in chapter 4 of the doctoral thesis and includes the following research questions and hypothesis:

a) How do assets influence the net maize income achieved by households of different wealth?

b) Which assets contribute to what extent towards the net maize income gap between households of different wealth?

c) How much contributes the return to assets towards the maize income gap between households of different wealth?

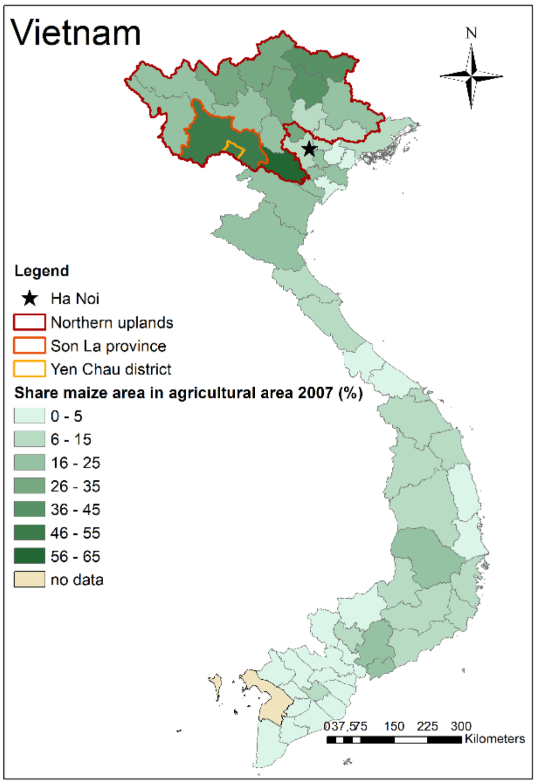
- Hypothesis 3: Assets as well as return to assets have an important effect on the maize income gap between households of different wealth. Different types of assets as well as different types of return to assets are differently important for the net maize income gap.

1.3. Survey implementation

1.3.1. Description of the research area

The Northern Uplands account for Vietnam's region with the highest average and total maize shares in cropping patterns (GSO, 2007). Among the ten provinces with the highest maize shares in 2007 seven were located in the Northern Uplands, i.e. Hoa Binh (60.5%), Son La (47.5%), Cao Bang (44.6%), Bac Kan (42.7%), Lao Cai (34.4%), Ha Giang (29.3%), and Tuyen Quang (25.3%) (Figure 1-3).[10]

Figure 1-3: Maize production in Vietnam 2007



Source: Own compilation based on GSO (2007)

The research of this doctoral thesis was conducted in Yen Chau district, Son La province, a rural district, located 300km west of Hanoi, at the National road 6, which links Hanoi with the West of the country (Saint-Macary, 2014). The research area is characterized by a hilly to mountainous environment (elevations of 281-1088 masl in Yen Chau district, 295-995 masl in our twenty research villages) (Saint-Macary, 2014), high levels of agroecological fragility (Minot et al., 2006; Tuan et al., 2014; Wezel et al., 2002b), high poverty rates (39% (2006) in Son La province, the fifths-highest in Vietnam (GSO, 2020), and 16.7% (2007) in our research sample), and a high share of ethnic minority people in the population (82.4% in Son La province (2009) (GSO, 2009) and 90.7% in our research sample).

Infrastructure in Yen Chau district is relatively weak with research villages mostly connected by dirt roads to the national road 6. Households are highly dependent on agriculture for their

[10] In comparison, average maize shares in agricultural area by region (provinces within regions) were 29.8% (11.5-60.5%) in the Northern Uplands, 14.6% (6.4-24.9%) in the Central Highlands, 12.2% (3.2-24.1%) in Northern Central and Central Coastal, 11.7% (3.1-23.2%) in the Red River Delta, 7.4% (1.4%-20.1%) in the South East, and 1.4% (0.1%-3.7%) in the Mekong River Delta, and 11.7% in entire Vietnam (GSO, 2007).

living with high shares of agricultural income (55.4% (2010) in total income in Son La province, the second-highest share in Vietnam (GSO, 2020), and 83.0-83.7% (2007-2010) agriculture income in household cash income in our research sample), high shares of upland agriculture in farm area (77.5-74.9% (2007-2010) in our research sample), and high shares of maize in total cropping patterns (47.5% (2007) in Son La province (GSO, 2007) and 72.5-75.0% (2007-2010) in our research sample).

1.3.2. Data collection

The research of this doctoral thesis was conducted as part of the larger collaborative research program on sustainable land-use systems in South East Asia, the Uplands program (SFB 564) within the subproject F2 (F2.3 for the years 2007 to 2009 and F2.4 for the years 2010 to 2012)[11] (see, for example, Saint-Macary, 2014). The research was implemented in the form of several rounds of detailed household level surveys and village level questionnaires between 2007 and 2011 in twenty villages and 300 households in Yen Chau district. The subprojects F2.3 and F2.4 were supervised by two project leaders and implemented by five PhD students (including the author) in four rounds between March 2007 and January 2008 (F2.3), one round in May to June (2009) (F2.3), and six rounds between March 2010 and September 2011 (F2.4).[12] The questionnaires covered a wide range of topics, including household demographic characteristics, household food and non-food expenditure, household income sources, household access to natural, physical, social, human, and financial capital, household risk attitudes, as well as household agricultural activities, including household maize production. The household surveys were each complemented by village level questionnaires that collected data on village level characteristics, such as ethnic composition, infrastructure access, etc.[13] This doctoral thesis here uses all socio-economic and agronomic data related to the analysis of maize production from the household and village level surveys from March 2007 until December 2010. The questionnaires were developed in collaboration with the other members of the research team in the Department of Rural Development Theory and Policy of the Institute of Agricultural Economics and Social Sciences in the Tropics and Subtropics of the University of Hohenheim (see also, Saint-Macary, 2014)[14]. Questionnaires were adapted to the local conditions and carefully pre-tested to make sure that questions fit the local context

[11] F2.3 (2007 to 2009) and F2.4 (2010 to 2012) refer to consecutive rounds of the same subproject F2 of the Uplands program (SFB 564).

[12] The author of this thesis implemented the household survey round in May to June (2009) as part of her Master thesis, two rounds of the household survey of F2.4 between March 2010 and November 2010 as part of her PhD thesis, and was part of the research team that implemented two out of the remaining four household survey rounds (F2.4) between December 2010 and September 2011 (as part of her PhD thesis).

[13] The surveys covered five PhD topics, including this thesis, which explains the many survey rounds and variety of topics.

[14] The Institute is now called "Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute)" at the University Hohenheim, Germany.

and that the wording was easily understandable to households. To conduct the interviews, local enumerators (native or living in the area) with educational backgrounds such as extension agents, teachers, etc. and knowledgeable about the area and the local customs were carefully selected and thoroughly trained (see also, Saint-Macary, 2014). Most of the local interviewers were familiar with the local language spoken in the area (Thai) and a large share of interviews could be conducted in this language. In remote Hmong villages local translators were hired if needed (see also, Saint-Macary, 2014). Filled out questionnaires were checked on site for consistency and rechecked by a data entry operator. Questionnaires were entered twice using SPSS Data entry double entry mode to avoid mistyping errors (see also, Saint-Macary, 2014).

1.3.3. Research design and sample selection

For the research sample, data were collected from 300 randomly selected households in Yen Chau district in a panel survey between the years 2007 and 2011. Sampling was based on a two-stage cluster strategy using the Probability to Size (PPS) method (Carletto, 1999). In the first stage, 20 villages were randomly selected Probability to Size (PPS) from a village level sampling frame encompassing all villages of the district, including information on the number of resident households. In the second stage, 15 households were randomly selected from the sampled villages' updated household lists. Since the first sampling step already accounts for differences in village sizes, the second sampling step automatically generates a self-weighted sample with all households in the district having equal probability to be selected (Carletto, 1999).

1.4. Outline of the thesis

The doctoral thesis is organized around five chapters. After this introduction in chapter 1 that presented the problem setting, research focus, research objectives, and methods of research implementation, chapter 2 presents the research concept, methodology, results, and discussion of the analysis on the first research topic (1) on how agricultural technology adoption, input intensification, and agricultural productivity differ in maize production by household wealth and over time, chapter 3 presents the research concept, methodology, results, and discussion of the analysis on the second research topic (2) on how risk aversion affects household fertiliser input levels in maize production based on household wealth, and chapter 4 presents the research concept, methodology, results, and discussion of the analysis on the third research topic (3) on how asset levels and returns to assets contribute to differences in maize productivity between households of different wealth. Chapter 5 summarizes the main research results of this doctoral thesis and draws the main conclusions.

2. Level and short-term changes in input use and agricultural productivity of maize

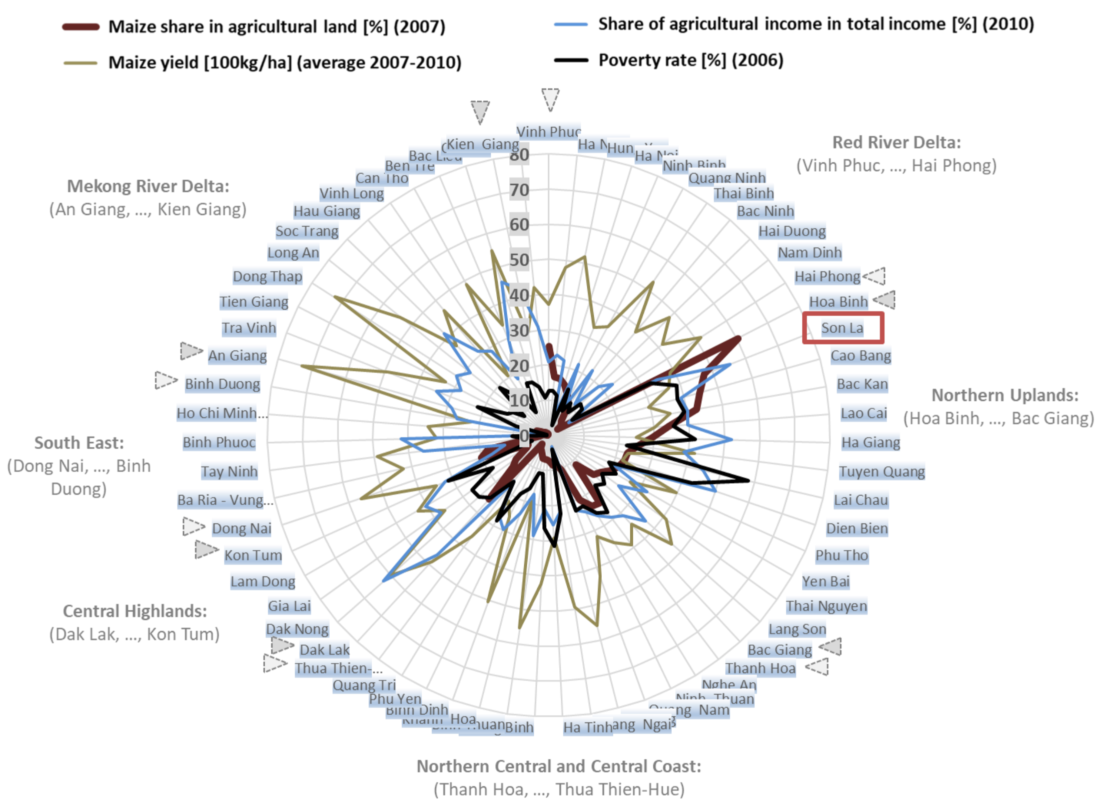
2.1. Introduction

While Vietnam's intensification efforts of the uplands reach back to the cooperative period, intensification and productivity increases during that time were small or negative (Hossain and Singh, 2000; Sadoulet et al., 2002). With the Doi Moi reforms that revised land tenure[15], that successively liberalized input and output markets, and that made farmers the main decision-makers, agriculture changed drastically in Vietnam's upland areas. Supported by the market-based reforms, government promotions, the increasing integration of upland farming systems into the national economy, and the increasing demand for meat, fish, fruits and vegetables fostered by income growth in the urban centres, intensification strategies in the Northern Uplands of Vietnam included the increased use of improved hybrid seed and fertiliser, the change from food (i.e. upland rice, maize, and cassava) to cash crops (such as commercialized maize production), the shift from swidden cultivation to permanent cropping, and increasing levels of agricultural diversification and regional specialization (Brandt and Benjamin, 2002; Keil et al., 2013; Leisz et al., 2005; Minot et al., 2006; Sadoulet et al., 2002; Sikor and Vi, 2005). One of these increasingly specialized and intensified agricultural systems in the Northern Uplands is maize production. While maize is a traditional upland crop, its commercialization and economic importance have tremendously increased (Keil et al., 2013; Wezel et al., 2002a). Nowadays, maize constitutes the second most important food and feed crop after rice in respect to the cultivated area in Vietnam (Nguyen, 2017). While maize in Vietnam is grown in different agroecological zones (Thanh et al., 2004), it is prominent and highly concentrated in the Northern Uplands (Thanh et al., 2004; Figure 2-1). Maize is moreover the crop that is predominantly grown in areas with high dependencies on agricultural income (Figure 2-1), by ethnic minorities, and by poor farmers (Thanh and Neefjes, 2005). In 2002 poverty rates among maize farmers were over 50% compared to only 29% of all other Vietnamese households (Thanh and Neefjes, 2005: 5). While 80% of maize output is used for animal feed, it also serves as a food substitute in case of rice shortage for poor people in the rural and mountainous regions (Nguyen, 2017; Thanh et al., 2004). Since a large share of maize production is used for industry, maize is a highly commercialized crop compared to rice that in the uplands is mostly used for subsistence (Ufer, 2010). While maize is particularly

[15] While the land stays in the ownership of the state, the 1993 land law granted users with five rights: the right to exchange, transfer, mortgage, inherit, and lease out the land. Use rights in the form of land use certificates are issued by 20 years for annual crop land and for 50 years for perennial crop land (Saint-Macary, 2014: 12).

suitable for the marginal upland areas, maize monoculture on steep slopes has also large environmental consequences, such as nutrient depletion and soil erosion, while at the same time the possibility for further area expansion of maize cultivation is limited (Nguyen, 2017; Thanh et al., 2004; Tuan et al., 2014). Therefore, any further increase in maize production and productivity will have to come from increased intensification (Nguyen, 2017). At the same time, many development obstacles in the Northern Uplands remain, like agroecological fragility, low levels of infrastructure and rural institutions, low levels of human capital and household assets, as well as high poverty (Minot et al., 2003, 2006; Tuyen, 2015). Hence, farmers have to overcome a series of obstacles to intensify production and to profitably participate in market-orientated cash crop production. Intensification and diversification of farming systems require higher investments, which makes the asset base of households more important for household production and incomes, while at the same time market risks have grown (Sadoulet et al., 2002; Sikor and Vi, 2005).

Figure 2-1: Maize share, maize yield, share of agricultural income, and poverty rate in Vietnam by province



Source: Own depiction based on GSO (2006, 2007, 2020)

In consequence, differentiation between households in the Northern Uplands compared to the pre-reform period has increased (Sadoulet et al., 2002; Sikor and Vi, 2005). The level of wealth and assets that may be needed to successfully intensify and diversify agricultural production may particularly put poor households at a disadvantage since they have a lower asset base and are less able to cope with household risks (Dercon and Christiaensen, 2011;

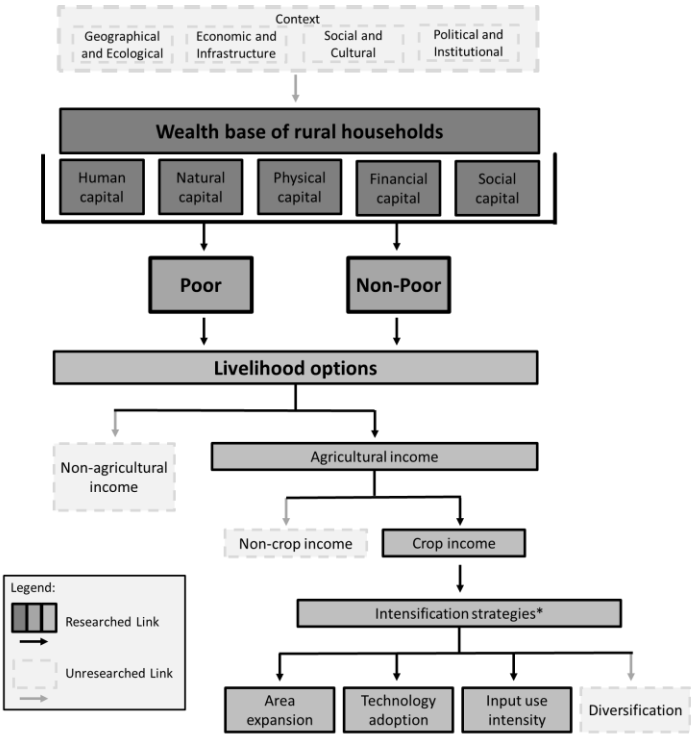
Tuyen, 2015; Zimmerman and Carter, 2003). At the same time, the poorer households in the Northern Uplands and Vietnam depend still the most on agricultural income (Minot et al., 2006; The World Bank, 2012). While the intensification of upland agriculture remains high on the policy agenda of Vietnam (Nguyen, 2017), evidence to quantify actual intensification levels in Vietnam's Northern upland farming systems in general and to quantify actual intensification levels in maize farming systems in the Northern Uplands in particular remains rare. While some studies look at maize marketing (Lançon et al., 2014), the factors that influence household allocation to maize (Keil et al., 2013), the overall tendencies in input use for maize at the provincial level (Nguyen, 2017), the technical efficiency of maize production in terms to yield (To-The and Nguyen-Anh, 2021), or the income gap between actual farmers practice and potential improved agricultural practice (Yen et al., 2013), none of these studies explicitly differentiates how technology adoption and intensification strategies between poor and non-poor households may differ. Therefore, this chapter answers questions about how technology adoption, intensification levels of maize input, and maize productivity differ between poor and non-poor households. This chapter (chapter 2) serves also as the extensive descriptive background for the econometric analysis in chapter 3 that analysis how risk influences fertiliser use in maize by the poor and the non-poor and chapter 4 that analysis which asset-based factors contribute to the net maize income gap per hectare of poor and non-poor households. The chapter proceeds as follows: Section 2.2. presents the conceptual framework and the methodology employed, Section 2.3. describes the empirical results of the analysis, and Section 2.4. discusses the empirical results and draws the conclusions for research and policy.

2.2. Conceptual framework and methodology

2.2.1. Conceptual framework

The growth of rural income can come from many sources, i.e. increased crop income, increased non-crop (livestock, fisheries, forestry) agricultural income, or increased non-farm income (Minot et al., 2006: 13). For crop income, increases can come from area expansion, intensification, such as the adoption of new technologies, higher cropping intensities, higher input use that increases yields, higher agricultural output prices, as well as crop diversification (especially crop diversification into high-value crops since crop diversification for risk management is often correlated with low-risk – low-return portfolios) (Dercon, 2002; Minot et al., 2006: 14). Adoption rates of technologies and intensity of input levels can however vary with the socio-economic characteristics of farmers, across regions, and over time (Evenson and Gollin, 2003; Feder et al., 1985; Rogers, 1962). The reasons for these variations follow from the household's problem that the "extent and intensity of technology adoption is a continuously temporal optimization problem given the awareness, experience, constraints, prices, and risks a household faces" (Feder et al., 1985). At the household level, constraints to technology adoption and intensification can be any lack of natural, human, physical, financial, and social capital (Scoones, 1998). However, these constraints do not have to be continuous across wealth terciles. Livelihood choices, such as technology adoption and intensification decisions, may bifurcate at some point in the wealth distribution because households may not have enough assets available to adopt certain technologies or intensify production when they are below a certain wealth threshold but instead adopt more conservative, low-risk strategies (Zimmerman and Carter, 2003). For this reason, this chapter follows the approach to first classify households into poor and non-poor households by wealth terciles and then intensively look at the adoption and intensification strategies of households regarding maize production (Figure 2-2).

Figure 2-2: Household pathways of intensification



Source: Own depiction

2.2.2. Empirical strategy and methodology

We first separate households by wealth status employing a Principal Component Analysis (PCA) that generates an individual wealth index for each household based on their asset base (Henry et al., 2003; Zeller et al., 2006).[16] After we group the households into wealth terciles

[16] The PCA method employed to generate the wealth index is described in detail in chapter 3.3.3, p.58. In our case, the significant assets identified to describe household wealth are: House exterior wall is made of bamboo, House floor is earth with no covering, Household has electricity, Household has own connection to

by their PCA-generated wealth score, we extensively analyse differences in household intensification strategies by wealth tercile with the help of quantitative descriptive methods. Variables of interest are analysed a) between wealth terciles within a year and b) between years within a wealth tercile using the following statistical tests as summarized in Table 2-1 (for an overview of how to select means tests see also Field, 2018). Tests are implemented with the support of the statistical analysis package STATA 15.

For continuous variables, we first determine whether the variable is normally distributed or not applying a $Shapiro - Wilk - test$ (Shapiro and Wilk, 1965). To test means for differences between wealth terciles within years, unpaired, normally distributed variables are tested by $Anova$ for multiple comparisons followed by $unpaired\ t - tests$ for single comparisons in post-hoc testing (STATA, 2017). In the same respect, unpaired, non-normally distributed variables are tested by $\mathrm{Kruskal - Wallis - test}$ (Kruskal and Wallis, 1952, 1953) for multiple comparisons followed by two-sample $\mathrm{Wilcoxon\ rank - sum\ (Mann - Whitney)\ tests}$ (Mann and Withney, 1947; Wilcoxon, 1945) for single comparisons in post-hoc testing.

Table 2-1: Means tests used for statistical analysis of descriptives

Type of variable	Type of comparison	Type of distribution of variable		(Means) test *MU=Multiple; S/ADH=Single/ad-hoc*			Adjustment multiple comparisons
Continuous	Normality tests	To be determined		Shapiro-Wilk normality test			none
Continuous	Equality of distribution	To be determined		Kolmogorov-Smirnov test			none
Continuous	Between wealth terciles within year	Normal		Multiple: ANOVA Single/ad-hoc: unpaired t-test			Bonferroni
		Non-normal		Multiple: Kruskal-Wallis-test Single/ad-hoc: Mann-Whitney test			
Continuous	Between years within wealth tercile	Normal		Multiple: Repeated-measurements-ANOVA Single/ad-hoc: paired t-test			Bonferroni
		Non-normal	Equal	Multiple: Skillings-Mack-test	Single/ad-hoc: signrank		
			Non-equal		Single/ad-hoc: signtest		
Categorical	Between wealth terciles within year	-		MU; S/ADH: Chi-squared		> 5	Bonferroni
				MU; S/ADH: Fisher's exact		<=5	
Categorical	Between years within wealth tercile	-		Single/ad-hoc: Symmetry -test		> 25	Bonferroni
				Single/ad-hoc: mid-p-test		<=25	

Source: Own depiction

For testing paired-means within wealth terciles between years, we test first for the equality of the variables' distribution using $\mathrm{Kolmogorov - Smirnov - test}$ (Kolmogorov, 1933; Smirnov, 1933). For paired, normally distributed variables we use $\mathrm{Repeated - measurements - ANOVA}$ for multiple comparisons followed by $\mathrm{paired\ t - tests}$ for single comparisons in post-hoc tests (STATA, 2017). For paired, non-normally distributed variables

electrical grid, Log(Total current value of cattle), Log(Total current value of television), Log(Total current value of motorcycle), Log(Total current value of living room furniture), Log(Total current value of cupboard).

we use $\text{Skillings} - \text{Mack} - \text{test}$ (Chatfield and Mander, 2009) for multiple comparisons followed by $\text{sign} - \text{rank} - \text{test}$ for equally distributed variable pairs or followed by $\text{sign} - \text{test}$ for non-equally distributed variable pairs for single comparisons in post-hoc tests (STATA, 2017).

To test unpaired-means in categorical variables for differences between wealth terciles within years, we use $Chi - squared\ (\mathrm{X}^2) - test$ (Pearson, 1900) or $Fisher's - exact - test$ (Fisher, 1935) in the case one category in the crosstabulations is equal or below 5 (Field, 2018: 839). To test paired-means in categorical variables for differences between years within wealth terciles, we use $Symmetry - test$ (STATA, 2017) or $mid - p - test$ in the case the discordant cells in the crosstabulations are below 25 (Fagerland et al., 2013; Pembury Smith and Ruxton, 2020).

Multiple comparisons in post-hoc tests are $Bonferroni - corrected$ adjusted error-probability-levels (p-levels) by the number of comparisons as the following:

$$\text{Bonferroni} - \text{correction of p} - \text{levels} = \alpha/k \tag{2.1}$$

with α = the level of error probability (i.e. α = 0.01, α = 0.05, α = 0.1) and k = the number of hypothesis to be tested (i.e. the number of multiple comparisons) (Field, 2018: 83).

2.2.3. Description of the regression samples

For the analysis in chapter 2 based on research question (1) “level and short-term changes in agricultural input use and productivity in maize production by household wealth”, we use the same households as in the regression and decomposition analysis of chapter 4 based on the research question (3) “impact of household asset levels and the return to assets on productivity differences in maize production between households of different wealth”(Table 2-2).

Table 2-2: Overview of the total sample and the regression/decomposition sample by year

	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
	All Households				Poorest				Middle				Wealthiest			
[N] Total sample	300	297	294	294	100	99	96	96	100	98	98	98	100	100	100	100
[N] Agricultural HH	294	291	287	287	100	99	94	94	94	92	94	94	100	100	99	99
[N] Maize growing HH	287	279	278	277	99	95	93	92	93	88	89	88	95	96	96	97
[N] Final RD sample	269	267	259	263	88	90	88	87	88	84	79	81	93	93	92	95
[%] Excluded maize growing HH from RD sample	6.3	4.3	6.8	5.1	11.1	5.3	5.4	5.4	5.4	4.5	11.2	8.0	2.1	3.1	4.2	2.1

Note: RD=regression/decomposition sample

Source: Own data

Households in the regression and decomposition sample of chapter 4 are excluded on a yearly basis based on the following criteria, (1) households with mineral fertiliser use above

4000 kg/ha, (2) households with yields above 20 t/ha, (3) households with negative gross margins, (4) households with missing values in any of the variables, and (5) households with outliers in their regression residuals defined by the interquartile range (Hamilton, n.d.).

For the analysis in chapter 3 based on the research question (2) “impact of risk aversion on fertiliser in maize production use by household wealth”, we use the data of all maize growing households that have valid risk preference data, i.e. for the self-assessment scale (DIW Berlin) and the lottery game (Holt and Laury, 2002) derived risk preference variables, as well as valid data on the PCA-generated wealth index (Total N=243), household income (Total N=235), and household expenditure (Total N=243) in the year 2010. The regression samples and the respective descriptives for the analysis in chapter 3 are described in detail in chapter 3.

2.3. Presentation of empirical results

2.3.1. Agricultural system and household characteristics

Table 2-3 shows the overview of household ethnic composition, agricultural production, sources of household income, and levels of per-capita household expenditure by wealth tercile in the research area based on the entire research sample.[17]

The share of households belonging to an ethnic minority group is very high in our research area. From 2007 to 2010, 76.1%, 14.5%, and below 1% of household heads belong to the ethnic minority groups Black Thai, Hmong, and the Kho Mu or Sinh Mun,[18] and 9.4% of household heads belong to the Kinh (ethnic Vietnamese) majority group on average. From the household heads, in the poorest tercile 44%, 47%, and 9%, in the middle tercile 0% [p<0.01], 86% [p<0.01], and 14% [ns], and in the wealthiest tercile 0% [p<0.01], 94% [p<0.01], and 6% [ns] belong to the Hmong, Black Thai, and Kinh ethnic group. Consequently, Hmong households belong relatively more often to the poorest tercile (100%), while 21%, 37%, and 42% of the Black Thai and 29%, 50%, and 21% of the Kinh households belong to the poorest, middle, and wealthiest tercile, respectively. Differences in ethnic composition between the middle and wealthiest terciles in any year and between years in all wealth terciles are not significantly different from zero.

Evaluating household daily per-capita expenditure shows that significant differences between wealth terciles exist. The poorest households reach the lowest per-capita daily expenditure of 10,600 VND (1.41 USD 2011 PPP) in 2007 and 10,518 VND (1.40 USD 2011 PPP) in 2010. In comparison, the middle tercile reaches a daily per-capita expenditure of 15,219 VND (2.02

[17] All other tables in this chapter that are related to maize production alone are based on the panel regression sample, which is also used for analysis in chapter 4 (see Table 2-2, p.22).

[18] In Table 2-3 the Kho Mu and Sinh Mun households are merged with Black Thai households for simplicity.

USD 2011 PPP) in 2007 and 13,971 VND (1.86 USD 2011 PPP) in 2010, and the wealthiest tercile reaches a daily per-capita expenditure of 20,686 VND (2.75 USD PPP) in 2007 and 16,588 VND (2.20 USD 2011 PPP) in 2010.[19] Compared to the poorest tercile in 2007 (2010), differences in daily per-capita expenditure are 43.6% [p<0.01] (32.8%, p<0.01) higher in the middle and 95.2% [p<0.01] (57.7%, p<0.01) higher in the wealthiest terciles. Differences compared to the middle tercile in 2007 (2010) are 35.9% [p<0.01] (18.7, p<0.01) higher in the wealthiest tercile, respectively. Differences in daily per-capita expenditure in 2010 compared to 2007 are not significantly different from zero in the poorest tercile (-0.8%, ns) but significantly different in the middle (-8.2%, p<0.01) and the wealthiest terciles (-19.8%, p<0.01).

Table 2-3 further shows that the share of agricultural households, the dependency on upland area, the engagement in maize cultivation, the extent of maize commercialization, as well as the dependency on cash income from agriculture, crop, and in particular maize production is very high in all wealth terciles.

The share of agricultural households, defined as households that have at least some land available for agricultural cultivation, is large in all wealth terciles in all years (> 93.9%) with hardly any differences between wealth terciles.[20] Comparisons across wealth terciles show a slightly lower share of agricultural households in the middle tercile (94.0%; 93.9%) compared to the poorest (100%, p<0.05; 100%, p<0.05) and wealthiest households (100%, p<0.05; 100% p<0.05) in 2007 and 2008, and no statistically significant differences between wealth terciles in the share of households engaged in agriculture (> 95.9%) in 2009 and 2010. Differences between years are not significantly different from zero in any wealth tercile.

Farm area available for cultivation is similar between wealth terciles and stable over the years. Farm area reaches 1.65, 1.69, 1.82, and 1.70 ha in the poorest tercile, 1.55, 1.50, 1.46, and 1.40 ha in the middle tercile, and 1.99, 1.96, 1.96, and 1.94 ha in the wealthiest tercile from 2007 to 2010, respectively. Differences in farm area between wealth terciles are only significantly different between the middle and the poorest in 2007 [p<0.1] and the middle and the wealthiest group in 2007 [p<0.1], 2008 [p<0.5], 2009 [p<0.01], and 2010 [p<0.01], otherwise not. Differences between years are never significantly different from zero in any wealth tercile.

[19] The conversion rate is 1 USD = 7528.385 VND in purchasing power parity (PPP) for private consumption in 2011 (The World Bank, 2020).

[20] Farm area includes all self-owned, borrowed, and rented in plots that households can use for agricultural production including land kept in fallow. Farm area does not include rented or borrowed out plots, i.e. any plot that is owned but not available for own agricultural production in the respective year.

Table 2-3: Overview of ethnicity, agricultural system, and maize production by household wealth tercile and year[1,2,3)]

	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
Variables	**All Households**				**Poorest**				**Middle**				**Wealthiest**			
Total sample [N]	300	297	294	294	100	99	96	96	100	98	98	98	100	100	100	100
HH head is Thai [%][4)]	76.0	75.8	76.2	76.2	48.0^{a}	47.5^{a}	47.9^{a}	47.9^{a}	86.0^{b}	85.7^{b}	85.7^{b}	85.7^{b}	94.0^{b}	94.0^{b}	94.0^{b}	94.0^{b}
HH head is Hmong [%]	14.7	14.8	14.3	14.3	44.0^{a}	44.4^{a}	43.8^{a}	43.8^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
HH head is Kinh [%]	9.3	9.4	9.5	9.5	8.0	8.1	8.3	8.3	14.0	14.3	14.3	14.3	6.0	6.0	6.0	6.0
Agricultural HH [%][5)]	98.0	98.0	97.6	97.6	100.0^{a}	100.0^{a}	97.9	97.9	94.0^{b}	93.9^{b}	95.9	95.9	100.0^{a}	100.0^{a}	99.0	99.0
Maize growing HH [%][6)]	97.6	95.9	96.9	96.5	99.0	96.0	98.9	97.9	98.9	95.7	94.7	93.6	95.0	96.0	97.0	98.0
Total farm area [m²][6)]	17,327 (12,031)	17,234 (11,840)	17,492 (11,382)	16,859 (11,369)	16,491 (13,098)	$16,926^{a,b}$ (13,034)	$18,156^{a,b}$ (12,807)	$17,048^{a,b}$ (12,323)	15,511 (8,999)	$15,036^{a}$ (8,563)	$14,607^{a}$ (8,637)	$13,961^{a}$ (8,541)	19.869 (13.053)	19.562^{b} (12.847)	$19,600^{b}$ (11,779)	$19,432^{b}$ (12,211)
Upland share in farm area [%][6)]	77.5 (21.3)			74.9 (24.7)	82.4^{a} (21.2)			79.6^{a} (24.9)	77.1^{b} (16.7)			70.7^{b} (24.3)	73.0^{b} (24.3)			74.6^{b} (24.2)
Maize share in farm area [%][6)]	77.6_{w} (20.3)	73.6_{x} (24.2)	72.5_{x} (23.8)	$74.2_{w,x}$ (23.1)	84.0^{a} (17.0)	78.1^{a} (24.9)	75.6 (22.0)	80.3^{a} (21.2)	77.1^{b} (17.6)	72.6^{b} (23.3)	73.4 (24.9)	70.8^{b} (25.3)	71.7^{b} (23.8)	69.9^{b} (23.8)	68.7 (23.9)	71.6^{b} (21.8)
Per-capita expenditure [VND/person/day][7,8)]	$15,502_{w}$ (6,548)			$13,734_{x}$ (4,676)	$10,600^{a}$ (4,810)			$10,518^{a}$ (4,430)	$15,219^{b}_{w}$ (4,721)			$13,971^{b}_{x}$ (3,881)	$20,686^{c}_{w}$ (5,707)			$16,588^{c}_{x}$ (3,580)
Agricultural share in cash income [%][7)]	83.0 (25.5)			79.4 (29.7)	84.3 (22.0)			82.5 (27.8)	83.4 (26.6)			77.0 (32.8)	81.4 (27.6)			78.7 (28.3)
Crop share in cash income [%][7)]	73.0 (27.4)			71.2 (31.5)	78.1^{a} (23.1)			76.4 (29.4)	$72.4^{a,b}$ (29.7)			68.8 (34.1)	68.4^{b} (28.3)			68.7 (30.3)
Maize share in cash income [%][7)]	64.9_{w} (28.7)			66.4_{x} (32.2)	72.8^{a} (25.5)			73.9^{a} (29.8)	$64.0^{a,b}$ (29.9)			$63.3^{a,b}$ (34.9)	58.0^{b}_{w} (28.9)			62.4^{b}_{x} (30.9)
Maize harvest share sold [%][9)]	94.4_{w} (16.7)	93.3_{w} (18.7)	95.4_{x} (11.8)	94.0_{y} (15.9)	94.8_{w} (10.1)	$92.7_{w,y}$ (15.4)	$97.0_{w,y}$ (6.3)	$94.7_{x,y,z}$ (13.1)	92.3_{w} (22.1)	93.1_{w} (20.9)	93.4_{x} (15.4)	$92.4_{x,y}$ (18.8)	96.0_{w} (15.6)	94.0_{w} (19.8)	95.8_{x} (12.1)	$94.7_{x,y}$ (15.5)

Note:

1) Descriptives in the table are based on the entire household sample.
2) Superscript **a,b,c** denotes significance at the p<0.05 level of error probability for unpaired means tests between wealth terciles within year. Multiple comparisons by wealth tercile are Bonferroni-corrected.
3) Subscript **w,x,y,z** denotes significance at the p<0.05 level of error probability for paired means tests between years within wealth terciles. Multiple comparisons by year are Bonferroni-corrected.
4) The total for Thai household heads includes also three household heads that belong to the ethnic group of Kho Mu or Sinh Mun each year.
5) Agricultural households are defined as households that cultivate agricultural land.
6) Computed from all agricultural households.
7) Computed from all households.
8) Values of 2010 are deflated using regional CPI (GSO, 2011). The conversion rate was 1 USD = 7528.385 VND in purchasing power parity (PPP) for private consumption in 2011 (The World Bank, 2020).
9) Computed from all maize growing households.

Source: Own data

Upland share is high in all wealth terciles, but the highest in the poorest. The poorest tercile cultivates an upland share of 82.4% (79.6%) in 2007 (2010), which is higher than the upland share of the middle (77.1%, $p<0.01$; 70.7%, $p<0.01$) and wealthiest terciles (73.0%, $p<0.01$; 74.6%, $p<0.01$) in 2007 and 2010. Differences between the middle and wealthiest tercile as well as differences in upland share between years by wealth tercile are not statistically different from zero.

Maize share in farm area is almost as high as the upland share in farm area. While households of all wealth terciles are equally often engaged in maize cultivation, i.e. over 97.9%, 93.6%, and 95% of households in the poorest, middle, and wealthiest terciles from 2007 to 2010 (differences between wealth terciles in any year and between years not statistically significantly different from zero), the poorest cultivate the highest maize shares in farm area. From 2007 to 2010 the poorest tercile cultivates a maize share of 84.0%, 78.1%, 75.6%, and 80.3% compared to the middle tercile with maize shares of 77.1% [$p<0.01$], 72.6% [$p<0.05$], 73.4% [ns], and 70.8% [$p<0.01$] and the wealthiest tercile with maize shares of 71.7% [$p<0.01$], 69.9% [$p<0.01$], 68.7% [$p<0.1$], and 71.6% [$p<0.01$], respectively. Differences between the middle and the wealthiest tercile and differences between years by wealth tercile are not significantly different from zero.

The share of agricultural income in household cash income, i.e. the share of household cash income generated from all crop, livestock, fish, and forest products, is high and statistically equal between all wealth terciles as well as stable over the years. The share of agricultural income in cash income reaches 84.3% (82.5%) in the poorest, 83.4% (77.0%) in the middle, and 81.4% (78.7%) in wealthiest terciles in 2007 (and 2010). Differences between wealth terciles and differences between years by wealth tercile are not significantly different from zero.

Crop income in cash income reaches 78.1% (76.4%) in the poorest tercile in 2007 (2010), which is similar compared to the middle and wealthiest terciles with 72.4% [ns] (68.8%, ns) and 68.4% [$p<0.05$] (68.7%, ns) in 2007 (2010), respectively. Differences between the middle and the wealthiest tercile and differences between years by wealth terciles are not significantly different from zero.

Maize income in cash income however is slightly higher in the poorest tercile. In 2007 (2010), the share of maize income in cash income reaches 72.8% (73.9%) in the poorest tercile, which is higher compared to the middle and wealthiest terciles with 64.0% [$p<0.1$] (63.3%, $p<0.1$) and 58.0% [$p<0.01$] (62.4%, $p<0.01$), respectively. Differences between the middle and the wealthiest tercile are not significantly different from zero. Differences between years are significantly different in the wealthiest tercile [$p<0.05$] and not significantly different in the middle and poorest terciles.

In terms of maize commercialization, that is the share of maize output sold, households show no differences between wealth terciles. The share of maize harvest sold is very high and statistically equal between wealth terciles in all years with some but small variations between years. Maize shares sold reach 94.8%, 92.7%, 97.0%, 94.7% in the poorest, 92.3%, 93.3%, 93.4%, 92.4% in the middle, and 96.0%, 94.0%, 95.8%, 94.7% in the wealthiest tercile from 2007 to 2010, respectively. Differences between years are significantly different in the poorest tercile for the yearly comparisons 2007/2010 [$p<0.05$], 2009/2010 [$p<0.05$], in the middle tercile for the yearly comparison 2007/2009, 2008/2009, 2007/2010, 2008/2010 [$p<0.05$], and in the wealthiest tercile for the yearly comparisons 2007/2009, 2008/2009, 2007/2010, 2008/2010 [$p<0.05$].

2.3.2. Maize production

Next, maize production (Table 2-4 to Table 2-11) is evaluated based on our regression sample.

The most important maize varieties used are the local Vietnamese hybrid variety LVN10, the non-local hybrid varieties NK (NK4300, NK54, NK66, NK67) and CP (CP888, CP999), as well as any mixes of LVN10/NK/CP varieties. Other mixes and varieties, including any non-hybrid varieties (not shown separately here), play a minor role only (Table 2-4).

While differences in seed variety patterns exist (the overall chi-square tests by wealth terciles for differences in entire crop mix are significantly different from zero for the years 2007 [$p<0.01$], 2008 [$p<0.05$], 2009 [$p<0.01$], and not significantly different from zero in 2010), dissimilarities in seed variety use by wealth terciles are modest in most years. Households from the poorest, middle, and wealthiest terciles grow similar shares of LVN10 (differences only significantly different between the poorest (35.6%) and middle (19.1%) [$p<0.05$] tercile in 2008), NK (differences only significantly different between the poorest (21.6%) and the wealthiest (40.2%) [$p<0.05$] tercile in 2009), CP (differences between wealth terciles never significantly different from zero in any year), and mixes of LVN10/NKs/CPs (differences significantly different between the poorest (9.1%) and the middle (23.9%) [$p<0.05$] in 2007, and the middle (36.7%) and wealthiest (19.6%) [$p<0.05$] in 2009). Shares of other varieties and mixes are somewhat more often different between wealth terciles, i.e. between the poorest (15.9%)/middle (2.3%) [$p<0.01$] as well as poorest (15.9%)/wealthiest (4.3%) [$p<0.05$] in 2007, the poorest (24.4%)/wealthiest (8.6%) [$p<0.05$] as well as middle (21.4%)/wealthiest (8.6%) [$p<0.05$] in 2008, and the poorest (20.5%)/middle (6.3%) [$p<0.05$] as well as poorest (20.5%)/wealthiest (5.4%) [$p<0.01$] terciles in 2009, and not statistically significantly different between any wealth terciles in 2010.

Maize seed variety patterns however change quickly in all wealth terciles over time, with the wealthiest and middle terciles switching more strongly first and the poorest following rather quickly so. Symmetry tests for changes in entire crop mix between years are significantly different in the poorest tercile for the years 2007/2009 [$p<0.01$], 2007/2010 [$p<0.01$], 2008/2010 [$p<0.01$], and 2009/2010 [$p<0.01$], in the middle tercile for the years 2007/2008 [$p<0.01$], 2007/2009 [$p<0.05$], 2007/2010 [$p<0.01$], and 2008/2010 [$p<0.01$], as well as for the wealthiest tercile for the years 2007/2008 [$p<0.05$], 2007/2009 [$p<0.05$], and 2007/2010 [$p<0.01$]. Any other yearly comparisons are not statistically significantly different from zero.

Table 2-4: Maize variety grown by household wealth tercile 2007-2010[1)]

	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
	HH growing LVN10 only [%]				**HH growing NK varieties only [%]**				**HH growing CP888/999 only [%]**				**HH growing LVN10/NK/CP mixes [%]**				**HH growing other varieties/mixes [%]**			
All HH	**49.07**	**27.72**	**23.55**	**12.93**	**17.10**	**25.09**	**29.73**	**49.43**	**11.52**	**8.61**	**8.88**	**5.70**	**14.87**	**20.60**	**27.03**	**19.39**	**7.43**	**17.98**	**10.81**	**12.55**
[%] Δ to poorest	-0.93	-7.84	-2.58	4.88	2.33	2.87	8.14	-8.04	1.30	4.17	3.20	-0.05	5.78	7.27	0.89	5.60	-8.47	-6.47	-9.64	-2.39
[%] Δ to 2007	-	-21.36	-25.52	-36.14	-	7.99	12.63	32.33	-	-2.91	-2.64	-5.82	-	5.73	12.16	4.52	-	10.54	3.38	5.12
N	[269]	[267]	[259]	[263]	[269]	[267]	[259]	[263]	[269]	[267]	[259]	[263]	[269]	[267]	[259]	[263]	[269]	[267]	[259]	[263]
Tests across years[2,3)]	07/08***	-	09/10***		07/08**	-	09/10***		-	-	-		-	-	-		07/08***	08/09*	-	
	07/09***	08/10***			07/09***	08/10***			-	-			07/09***	-			-	-		
	07/10***				07/10***				-				-				-			
Poorest (W1)	**50.00**	**35.56**	**26.14**	**8.05**	**14.77**	**22.22**	**21.59**	**57.47**	**10.23**	**4.44**	**5.68**	**5.75**	**9.09**	**13.33**	**26.14**	**13.79**	**15.91**	**24.44**	**20.45**	**14.94**
[%] Δ to 2007	-	-14.44	-23.86	-41.95	-	7.45	6.82	42.70	-	-5.78	-4.55	-4.48	-	4.24	17.05	4.70	-	8.54	4.55	-0.97
N	[88]	[90]	[88]	[87]	[88]	[90]	[88]	[87]	[88]	[90]	[88]	[87]	[88]	[90]	[88]	[87]	[88]	[90]	[88]	[87]
Tests across years[2,3)]	07/08**	-	09/10***		-	-	09/10***		-	-	-		-	-	-		-	-	-	
	07/09***	08/10***			-	08/10***			-	-			07/09**	-			-	-		
	07/10***				07/10***				-				-				-			
Middle (W2)	**47.73**	**19.05**	**20.25**	**16.05**	**13.64**	**22.62**	**26.58**	**40.74**	**12.50**	**10.90**	**10.13**	**4.94**	**23.86**	**25.00**	**36.71**	**25.93**	**2.27**	**21.43**	**6.33**	**12.35**
[%] Δ to poorest	-2.27	-16.51	-5.88	8.00	-1.14	0.40	4.99	-16.73	2.27	7.46	4.44	-0.81	14.77	11.67	10.57	12.13	-13.64	-3.02	-14.13	-2.60
[%] Δ to 2007	-	-28.68	-27.47	-31.68	-	8.98	12.95	27.10	-	-0.60	-2.37	-7.56	-	1.14	12.85	2.06	-	19.16	4.06	10.07
N	[88]	[84]	[79]	[81]	[88]	[84]	[79]	[81]	[88]	[84]	[79]	[81]	[88]	[84]	[79]	[81]	[88]	[84]	[79]	[81]
Tests across years[2,3)]	07/08***	-	-		-	-	-		-	-	-		-	-	-		07/08***	08/09**	-	
	07/09***	-			-	08/10**			-	-			-	-			-	-		
	07/10***				07/10***				-				-				-			
Wealthiest (W3)	**49.46**	**27.96**	**23.91**	**14.74**	**22.58**	**30.11**	**40.22**	**49.47**	**11.83**	**9.68**	**10.87**	**6.32**	**11.83**	**23.66**	**19.57**	**18.95**	**4.30**	**8.60**	**5.43**	**10.53**
[%] Δ to poorest	-0.54	-7.60	-2.22	6.69	7.81	7.89	18.38	-8.00	1.60	5.23	5.19	0.57	2.74	10.32	-6.57	5.15	-11.61	-15.84	-15.02	-4.42
[%] Δ to 2007	-	-21.51	-25.55	-34.73	-	7.53	17.64	26.89	-	-2.15	-0.96	-5.51	-	11.83	7.74	7.12	-	4.30	1.13	6.23
N	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]
Tests across years[2,3)]	07/08***	-	-		-	-	-		-	-	-		07/08**	-	-		-	-	-	
	07/09***	08/10*			07/09***	08/10**			-	-			-	-			-	-		
	07/10***				07/10***				-				-				-			
Tests by wealth terciles[2,4)]	-	W1/2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	W1/2***	-	W1/2**	-
	-	-	-	-	-	-	W1/3**	-	-	-	-	-	W1/2**	-	-	-	W1/3**	W1/3**	W1/3***	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	W2/3**	-	-	W2/3**	-	-

Note:

1) Percentages may not add up to 100% due to rounding.
2) Level of error probability: [***] p<0.01, [**] p<0.05, [*] p<0.1, [-] not significantly different from zero.
3) Symmetry (mid-p) tests for paired-comparisons between years within variety and wealth tercile. Multiple comparisons between years Bonferroni-corrected. Overall comparisons for differences in entire crop mix between years within wealth terciles: poorest tercile 2007/2009 [p<0.01], 2007/2010 [p<0.01], 2008/2010 [p<0.01], and 2009/2010 [p<0.01]; middle tercile 2007/2008 [p<0.01], 2007/2009 [p<0.05], 2007/2010 [p<0.01], and 2008/2010 [p<0.01]; wealthiest tercile 2007/2008 [p<0.05], 2007/2009 [p<0.05], and 2007/2010 [p<0.01]; any other comparisons [ns].
4) $\chi 2$ – (Fisher's exact) tests for comparisons between wealth terciles within a single variety and a single year. Multiple comparisons between wealth terciles Bonferroni-corrected. Overall comparisons of differences in the entire crop mix (all varieties) between all three wealth terciles (simultaneously) within years: 2007 [p<0.01], 2008 [p<0.05], 2009 [p<0.01], 2010 [ns].

Source: Own data

The biggest changes in seed variety patterns thereby are in the local hybrid LVN10 and the foreign NK varieties in all wealth terciles. LVN10 use decreases from the most important variety in 2007 (grown by 49.1% of all households) to the third most important variety in 2010 (grown by 12.9% of all households) (symmetry test [p<0.01]). At the same time, the use of foreign hybrid NK varieties increases from the second most important variety in 2007 (grown by 17.1% of all households) to the most important variety in 2010 (grown by 49.4% of all households) (symmetry test [p<0.01]). Other varieties and variety mixes are less important and their use more stable over time, varying between 5.7-11.5% for CP varieties, 14.9-27.0% for LVN10/NK/CP mixes, and 7.4-18.0% for other mixes/varieties in 2007 to 2010.

Separated by wealth terciles, the share of households that grow LVN10 in the poorest tercile decreases from 50.0% (1st) in 2007, to 35.6% (1st) in 2008, to 26.1% (2nd) in 2009, to 8.1% (4th) in 2010 (symmetry tests for yearly comparisons 2007/2008 [p<0.05]; 2007/2009, 2007/2010, 2008/2010, 2009/2010 [p<0.01]; all other [ns]). In the middle tercile the share of households that grow LVN10 decreases from 47.7% (1st) in 2007, to 19.1% (4th) in 2008, to 20.3% (3rd) in 2009, to 16.1% (3rd) in 2010 (symmetry tests for yearly comparisons 2007/2008, 2007/2009, 2007/2010 [p<0.01]; all other [ns]). In the wealthiest tercile the share of households that grow LVN10 decreases from 49.5% (1st) in 2007, to 28.0% (2nd) in 2008, to 23.9% (2nd) in 2009, to 14.7% (3rd) in 2010 (symmetry tests for yearly comparisons 2007/2008, 2007/2009, 2007/2010 [p<0.01]; 2008/2010 [p<0.1]; all other [ns]).

The share of households that grow NK varieties in the poorest tercile increases from 14.8% (3rd) in 2007, to 22.2% (3rd) in 2008, to 21.6% (3rd) in 2009, to 57.5% (1st) in 2010 (symmetry tests for yearly comparisons 2007/2010, 2008/2010, 2009/2010 [p<0.01]; all other [ns]). In the middle tercile the share of households that grow NK varieties increases from 13.6% (3rd) in 2007, to 22.6% (2nd) in 2008, to 26.6% (2nd) in 2009, to 40.7% (1st) in 2010 (symmetry tests for yearly comparisons 2007/2010, 2008/2010 [p<0.01]; all other [ns]). In the wealthiest tercile the share of households that grow NK varieties increases from 22.6% (2nd) in 2007, to 30.1% (1st) in 2008, to 40.2% (1st) in 2009, to 49.5% (1st) in 2010 (symmetry tests for yearly comparisons 2007/2009, 2007/2010 [p<0.01]; 2008/2010 [p<0.05]; all other [ns]).

CP varieties reach generally small shares in the variety mix independent of wealth tercile, and their share does not change over the years. Shares of households that grow CP varieties in the poorest tercile are 10.2%, 4.4%, 5.7%, and 5.8% (symmetry tests for yearly comparisons [ns]), in the middle tercile 12.5%, 10.9%, 10.1%, and 4.9% (symmetry tests for yearly comparisons [ns]), and in the wealthiest tercile 11.8%, 9.7%, 10.9%, and 6.3% (symmetry tests for yearly comparisons [ns]) in the years 2007, 2008, 2009, and 2010, respectively.

Mixes of LVN10/NK/CP are more frequently employed but less used than the single varieties LVN10 and NK combined in all terciles, with some variation in utilization between years. In the poorest tercile the share of households that grow LVN10/NK/CP mixes reaches 9.1% (5th), 13.3% (4th), 26.1% (1st), and 13.8% (3rd) (symmetry tests for yearly comparisons 2007/2009 [p<0.05]; all other [ns]), in the middle tercile 23.9% (2nd), 25.0% (1st), 36.7% (1st), and 25.9% (2nd) (symmetry tests for yearly comparisons [ns]), and in the wealthiest tercile 11.8% (3rd), 23.7% (3rd), 19.6% (3rd), and 19.0% (2nd) (symmetry tests for yearly comparisons 2007/2008 [p<0.05]; all other [ns]) for the years 2007 to 2010, respectively.

Other varieties and variety mixes, including the non-hybrid varieties, are less important in any wealth tercile and used without much yearly variation. Other varieties and variety mixes reach among the poorest households shares of 15.9%, 24.4%, 20.5%, and 14.9% (symmetry tests for yearly comparisons [ns]), in the middle tercile 2.3%, 21.4%, 6.3%, and 12.4% (symmetry tests for yearly comparisons 2007/2008 [p<0.01]; 2008/2009 [p<0.05]; all other [ns]), and in the wealthiest tercile 4.3%, 8.6%, 5.4%, and 10.5% (symmetry tests for yearly comparisons [ns]).

Following, Table 2-5 evaluates the quantity, purchase type (directly purchased, on-loan), prices, and costs of households seed input use.

The quantity of seed input use is similar for all wealth terciles and stable over time. Changes in seed variety patterns do not have a clear impact on the quantity of seed used.

Seed quantity is between 21.3-22.4 kg/ha in the poorest, 22.2-24.0 kg/ha in the middle, and 21.4-22.8 kg/ha in the wealthiest tercile (differences not statistically significantly different between wealth tercile by year and between years by wealth tercile). At the aggregated household level changes in seed amount between 2007 (22.2 kg/ha) to 2008 (23.0 kg/ha) [3.5%, p<0.01] are statistically significantly different, otherwise not.

Large differences however exist when looking at the decision (or necessity) of households to buy their seed input on-loan.[21] Differences in input loan outtake between the poorest and the other wealth terciles are large and significant. From 2008 to 2010, the share of households that bought seed input on-loan is in the poorest tercile 75.3%, 73.6%, and 63.2% (differences to the middle and wealthiest terciles [p<0.01] in all years), in the middle tercile 44.2%, 43.4%, and 38.3% (differences to the wealthiest tercile [p<0.1] in 2010, otherwise [ns]), and in the wealthiest tercile 42.4%, 34.1%, and 22.1%, respectively. While the share of households in the poorest and middle terciles is stable (comparisons between years [ns]), the share of households that buy seed on-loan in the wealthiest terciles is declining (differences between years 2008/2010 [p<0.05]; 2009/2010 [p<0.1]).

[21] Loan in the context of our research area refers mostly to delayed payment arrangements, where the input provider grants the farmer in-kind credit that has to be paid after harvest with a higher price, or tied buying-input-selling-output arrangements, where the implied interest rate is incorporated in the contract, as well as other formal or informal credit sources. By and large, these shopkeeper and trader based payment arrangements are widely accessible in the research area, and since they do not require any other formal or informal credit source, they are widely popular also among poorer households that otherwise might have hardly any access to other credit sources (Saint-Macary, 2014).

Table 2-5: Maize seed input by household wealth tercile 2007-2010

	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
Mean (SD)	**Seed input [kg/ha]**				**Share HH that buy seed input on-loan [%][1,2)]**				**Seed input prices as paid [000 VND/kg]**				**Total seed input cost [000 VND/ha]**				**Share seed input cost in total input cost [%][1)]**			
All HH	**22.24** **(8.45)**	**23.01** **(8.29)**	**22.31** **(8.11)**	**21.70** **(7.12)**	—	**54.25**	**50.39**	**40.68**	**39.61** **(15.98)**	**58.25** **(21.13)**	**70.61** **(14.13)**	**70.56** **(18.49)**	**876** **(479)**	**1,317** **(644)**	**1,572** **(647)**	**1,540** **(658)**	**26.63** **(19.81)**	**24.89** **(14.64)**	**28.01** **(17.09)**	**24.71** **(11.87)**
[%] Δ to poorest	4.37	2.82	3.40	0.44	—	-21.04	-23.17	-22.53	0.80	-1.88	-4.78	-10.20	6.80	2.17	-1.36	-10.28	-11.72	-6.86	-9.23	-5.42
[%] Δ to 2007	-	3.46	0.31	-2.47	—	-	-3.86	-13.57	-	47.08	78.32	78.15	-	50.35	79.57	75.82		-1.74	1.40	-1.92
N	[269]	[267]	[259]	[263]	—	[247]	[254]	[263]	[269]	[267]	[259]	[263]	[269]	[267]	[259]	[263]	[269]	[267]	[259]	[263]
Tests across years[3,4)]	07/08*** - -	- -	-		— — —	- 08/10***	09/10*		07/08*** 07/09*** 07/10***	08/09*** 08/10***	-		07/08*** 07/09*** 07/10***	08/09*** 08/10***	-		- 07/09*** -	08/09*** -	09/10*	
Poorest (W1)	**21.31** **(6.74)**	**22.38** **(7.38)**	**21.58** **(7.56)**	**21.60** **(6.78)**	—	**75.29**	**73.56**	**63.22**	**39.29** **(16.03)**	**59.37** **(21.80)**	**74.16** **(13.84)**	**78.57** **(18.95)**	**820** **(360)**	**1,289** **(536)**	**1,594** **(631)**	**1,717** **(729)**	**38.34** **(27.74)**	**31.76** **(20.09)**	**37.24** **(23.25)**	**30.13** **(16.25)**
[%] Δ to 2007	-	5.02	1.25	1.34	—	-	-1.73	-12.08	-	51.09	88.72	99.96	-	57.16	94.31	109.29		-6.59	-1.11	-8.22
N	[88]	[90]	[88]	[87]	—	[85]	[87]	[87]	[88]	[90]	[88]	[87]	[88]	[90]	[88]	[87]	[88]	[90]	[88]	[87]
Tests across years[3,4)]	- - -	- -	-		— — —	- -	-		07/08*** 07/09*** 07/10***	08/09*** 08/10***	-		07/08*** 07/09*** 07/10***	08/09*** 08/10***	-		- - -	08/09*** -	09/10**	
Middle (W2)	**23.43** **(11.07)**	**23.96** **(10.22)**	**23.10** **(9.06)**	**22.20** **(7.65)**	— —	**44.16**	**43.42**	**38.27**	**38.88** **(14.57)**	**56.87** **(19.03)**	**70.24** **(14.02)**	**65.96** **(16.68)**	**929** **(617)**	**1,352** **(740)**	**1,641** **(783)**	**1,467** **(610)**	**21.87** **(12.44)**	**21.84** **(9.01)**	**24.68** **(12.11)**	**21.55** **(7.25)**
[%] Δ to poorest	9.91	7.06	6.94	2.79	—	-31.14	-30.14	-24.95	-1.06	-4.20	-5.28	-16.05	13.27	4.89	2.95	-14.54	-16.48	-9.92	-12.56	-8.58
[%] Δ to 2007	-	2.29	-1.40	-5.22	—	-	-0.73	-5.88	-	46.29	80.67	69.66	-	45.54	76.59	57.91		-0.03	2.82	-0.32
N	[88]	[84]	[79]	[81]	—	[77]	[76]	[81]	[88]	[84]	[79]	[81]	[88]	[84]	[79]	[81]	[88]	[84]	[79]	[81]
Tests across years[3,4)]	- - -	- -	-		— — —	- -	-		07/08*** 07/09*** 07/10***	08/09*** 08/10***	-		07/08*** 07/09*** 07/10***	08/09*** -	-		- 07/09** -	08/09* -	-	
Wealthiest (W3)	**22.01** **(6.85)**	**22.77** **(7.11)**	**22.34** **(7.78)**	**21.35** **(7.02)**	—	**42.35**	**34.07**	**22.11**	**40.60** **(17.28)**	**58.42** **(22.40)**	**67.53** **(13.86)**	**67.15** **(17.26)**	**879** **(425)**	**1,313** **(651)**	**1,493** **(519)**	**1,441** **(601)**	**20.05** **(8.55)**	**21.01** **(9.30)**	**22.05** **(7.58)**	**22.43** **(8.08)**
[%] Δ to poorest	3.25	1.72	3.44	-1.15	—	-32.94	-39.50	-41.11	3.31	-1.60	-8.93	-14.54	7.12	1.82	-6.36	-16.06	-18.29	-10.75	-15.19	-7.69
[%] Δ to 2007	-	3.46	1.52	-2.98	—	-	-8.29	-20.25	-	43.91	66.35	65.41	-	49.39	69.86	64.00		0.96	2.00	2.38
N	[93]	[93]	[92]	[95]	—	[85]	[91]	[95]	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]
Tests across years[3,4)]	- - -	- -	-		— — —	- 08/10***	09/10*		07/08*** 07/09*** 07/10***	08/09*** 08/10***	-		07/08*** 07/09*** 07/10***	08/09*** -	-		- 07/09** -	- -	-	
Tests by wealth terciles[3,5)]	- - -	- - -	- - -	- - -	— — —	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** W2/3*	- - -	- - -	- W1/3*** -	W1/2*** W1/3*** -	- - -	- - -	- - -	W1/2** W1/3** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -

Note:

1) Percentages may not add up to 100% due to rounding.
2) Descriptives for this variable do not include the data of twenty (2008) and five (2009) households with missing values. 2007 no data.
3) Level of error probability: [***] p<0.01, [**] p<0.05, [*] p<0.1, [-] not significantly different from zero.
4) Repeated-measurements ANOVA followed by paired t-tests // Skillings-Mack-test followed by sign-(rank)-tests // Symmetry- (mid-p) tests for comparisons between years within wealth terciles. Multiple comparisons between years Bonferroni-corrected.
5) ANOVA followed by unpaired t-tests // Kruskal-Wallis-test followed by Mann-Whitney-tests // $\chi 2$ – (Fisher's exact) tests for comparisons between wealth terciles within years. Multiple comparisons between wealth terciles Bonferroni-corrected.

Source: Own data

Table 2-6: Maize seed input prices separated by seed variety, payment type, and wealth tercile 2008-2010

	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
Mean (SD)	**LVN10 input price [000 VND/kg]**			**NK input price [000 VND/kg]**			**CP input price [000 VND/kg]**			**Other/mixes input price [000 VND/kg]**		
➢ *No-loan (direct) seed input prices*												
All HH	**40.85**	**56.69**	**46.25**	**64.86**	**71.72**	**73.16**	**51.06**	**57.26**	**54.62**	**53.40**	**63.34**	**61.18**
	(20.14)	(13.58)	(10.49)	(17.85)	(9.07)	(9.25)	(13.83)	(11.61)	(9.84)	(21.25)	(10.54)	(13.69)
[%] Δ to poorest	42.01	11.45	-9.76	-6.20	-8.53	-3.34	-	-	-8.97	-14.60	-0.69	-7.36
N	[28]	[20]	[24]	[32]	[39]	[70]	[10]	[14]	[13]	[43]	[53]	[49]
Poorest	**28.76**	**50.87**	**51.25**	**69.15**	**78.41**	**75.68**	**-**	**-**	**60.00**	**62.52**	**63.78**	**66.04**
(W1)	(9.55)	(10.38)	(7.80)	(10.46)	(27.67)	(12.91)	(-)	(-)	(8.12)	(27.93)	(8.45)	(18.86)
N	[8]	[4]	[4]	[4]	[3]	[19]	[0]	[0]	[4]	[9]	[16]	[5]
Middle	**48.55**	**63.80**	**38.38**	**62.55**	**69.94**	**70.24**	**53.13**	**59.00**	**57.50**	**55.00**	**64.06**	**63.39**
(W2)	(13.58)	(12.14)	(7.73)	(16.56)	(7.37)	(7.52)	(15.11)	(7.48)	(3.70)	(22.00)	(13.36)	(10.42)
[%] Δ to poorest	68.82	25.43	-25.12	-9.54	-10.80	-7.20	-	-	-4.17	-12.04	0.44	-4.02
N	[7]	[7]	[8]	[11]	[12]	[17]	[6]	[5]	[4]	[19]	[19]	[21]
Wealthiest	**44.13**	**53.75**	**49.83**	**65.34**	**71.78**	**73.21**	**47.96**	**56.30**	**48.00**	**45.89**	**62.18**	**58.10**
(W3)	(24.97)	(14.71)	(10.36)	(20.42)	(5.99)	(7.25)	(13.11)	(13.71)	(11.79)	(13.00)	(9.25)	(15.03)
[%] Δ to poorest	53.43	5.67	-2.76	-5.50	-8.46	-3.27	-	-	-20.00	-26.60	-2.50	-12.02
N	[13]	[9]	[12]	[17]	[24]	[34]	[4]	[9]	[5]	[15]	[18]	[23]
Tests by wealth terciles[1,2]	-	-	W1/2*	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	W2/3**	-	-	-	-	-	-	-	-	-
➢ *On-loan seed input prices*												
All HH	**52.59**	**67.97**	**58.38**	**79.75**	**83.51**	**89.42**	**62.69**	**71.33**	**61.00**	**61.05**	**80.17**	**72.80**
	(11.59)	(9.15)	(13.80)	(30.01)	(14.11)	(15.60)	(10.36)	(8.11)	(19.80)	(17.72)	(12.45)	(16.29)
[%] Δ to poorest	1.95	-3.16	-18.54	2.74	-1.35	-1.77	1.77	1.33	29.79	-0.96	-1.43	-5.39
[%] Δ on-/no-loan[1,3]	28.76***	19.90***	26.23***	22.97**	16.43***	22.23***	22.78**	24.57***	11.69***	14.34**	26.57***	18.99***
N	[42]	[40]	[10]	[27]	[35]	[60]	[12]	[9]	[2]	[53]	[44]	[35]
Poorest	**51.59**	**70.19**	**71.67**	**77.62**	**84.65**	**91.03**	**61.60**	**70.40**	**47.00**	**61.64**	**81.33**	**76.94**
(W1)	(12.65)	(6.87)	(2.89)	(28.86)	(13.88)	(17.15)	(14.28)	(7.77)	(0.00)	(13.45)	(10.60)	(17.67)
[%] Δ on-/no-loan[1,3]	79.36***	37.99***	39.84**	12.26	7.97	20.27***	-	-	-	-1.41	27.52***	16.51
N	[23]	[19]	[3]	[14]	[15]	[31]	[4]	[5]	[1]	[23]	[25]	[20]
Middle	**48.51**	**68.67**	**48.76**	**74.15**	**90.71**	**85.94**	**65.39**	**73.00**	**-**	**56.17**	**74.68**	**66.18**
(W2)	(6.49)	(8.01)	(11.82)	(40.03)	(16.38)	(11.69)	(10.14)	(10.00)	(-)	(15.48)	(13.48)	(12.54)
[%] Δ to poorest	-4.03	-2.17	-31.96	-4.47	7.16	-5.59	6.15	-0.57	-	-8.87	-8.18	-13.98
[%] Δ on-/no-loan[1,3]	1.96	7.63	27.06	18.56	29.70**	22.36***	23.08	18.64*	-	2.14	16.57**	4.41
N	[7]	[8]	[5]	[5]	[7]	[16]	[4]	[3]	[0]	[18]	[15]	[10]
Wealthiest	**56.32**	**64.31**	**62.50**	**86.98**	**78.31**	**89.87**	**61.08**	**80.00**	**75.00**	**67.25**	**93.51**	**69.45**
(W3)	(11.59)	(11.88)	(10.61)	(28.14)	(11.99)	(16.35)	(8.50)	(0.00)	(0.00)	(25.91)	(8.74)	(14.51)
[%] Δ to poorest	9.17	-8.38	-12.79	12.05	-7.50	-1.27	-0.84	13.64	59.57	9.09	14.97	-9.74
[%] Δ on-/no-loan[1,3]	27.62	19.64	25.42**	33.11**	9.10*	22.76***	27.37	-	-	46.53**	50.37***	19.52
N	[12]	[13]	[2]	[8]	[13]	[13]	[4]	[1]	[1]	[12]	[4]	[5]
Tests by wealth terciles[2,3]	-	-	W1/2**	-	-	-	-	-	—	-	-	-
	-	-	-	-	-	-	-	—	—	-	-	-
	-	-	-	-	-	-	-	—	—	-	W2/3**	-

Note:

1) Level of error probability: [***] p<0.01, [**] p<0.05, [*] p<0.1, [-] not significantly different from zero. [—] Does not apply.
2) ANOVA followed by unpaired t-tests // Kruskal-Wallis-test followed by Mann-Whitney-tests for comparisons between wealth terciles within years. Multiple comparisons between wealth terciles Bonferroni-corrected.
3) Unpaired t-test // Mann-Whitney test.

Source: Own data

Seed prices per kg seed, separated by type of variety and whether the household buys seed input on-loan or not, are not consistently different between wealth terciles (Table 2-6).

While between 2007 and 2010 LVN10, NK, CP, and other/mixes acquired by some loan arrangement are on average 21.3% [p<0.05] more expensive[22] than when directly purchased, seed input price differences separated by variety and payment type across wealth terciles are mostly insignificantly different from zero. The only significant differences in seed input prices between wealth terciles are the direct prices for LVN10 in 2010 (poorest/middle [p<0.1]; middle/wealthiest [p<0.05]), on-loan prices for LVN10 in 2010 (poorest/middle [p<0.05]), and on-loan prices for other varieties/mixes in 2009 (middle/wealthiest [p<0.05]). Any other comparisons for differences in separated seed prices between wealth terciles are not significantly different from zero.

The similar is true when correlating prices with distance measures, such as walking minutes to the paved road, distance (km) to the province capital Yen Chau (YC), and distance (km) to the closest market. Both direct and loan-based seed input prices by variety are not consequently correlated with these distance measures either (results of the correlations not shown here).[23]

Given all these effects, i.e. variety choice (i.e. NK is 45.2% more expensive than LVN10, p<0.01)[24], purchase arrangements (i.e. whether the household purchased seed directly or on-loan), and to some extent distance measures (for those seed prices which are correlated to distance through household wealth), effective, that is final seed input prices per kg seed input used, are similar in all wealth terciles in 2007 and 2008 and significantly higher in the poorest tercile compared to the middle and wealthiest terciles in 2009 and 2010 (Table 2-5). Differences in effective seed input prices between all wealth terciles are not significantly different from zero in 2007 and 2008, and significantly higher in the poorest compared to the wealthiest tercile in 2009 (by 8.9% [p<0.01]; poorest/middle 5.3% [ns]), and significantly higher in the poorest compared to the middle (16.1%, p<0.01) and the wealthiest tercile (14.5%, p<0.01) in 2010, the year when seed variety patterns are statistically not different between wealth terciles. Differences in effective seed prices between the middle and wealthiest terciles are not statistically significantly different from zero in any year.

---

[22] Unweighted sum of yearly differences (weighted: 19.2%, p<0.01) between direct/on-loan LVN10, NK, CP, and other varieties/mixes price comparisons; [p<0.05] refers to the minimum level of error probability of each yearly variety-based comparison (see Table 2-6). Unweighted (weighted) difference between direct/on-loan prices are 25.0% (27.2%, p<0.01) for LVN10, 20.5% (20.8%, p<0.01) for NK, 19.7% (20.6%, p<0.01) for CP, and 20.0% (18.2%, p<0.01) for other varieties/mixes between 2008 and 2010, respectively.

[23] Correlations (Pearson correlation coefficient) significantly different are: distance to paved road & NK no-loan price (0.26, p<0.01), distance to market & other varieties/mixes no-loan price (0.35, p<0.01), distance to Yen Chau & NK no-loan price (0.17, p<0.05), other varieties/mixes no-loan price (0.28, p<0.01), other varieties mixes on-loan price (0.19, p<0.05).

[24] Unweighted average for differences between direct and on-loan LVN10 and NK variety seed input price comparisons from 2008-2010 (p<0.01), refers to the single comparisons between direct and on-loan LVN10 and NK prices from 2008-2010 (weighted average 46.8%, p<0.01).

As consequence of the similar seed input quantity used and the effective seed prices paid by wealth tercile, total seed input costs are not statistically different between any of the wealth terciles in 2007 to 2009 and significantly higher in the poorest tercile by 14.5% [$p<0.05$] and by 16.1% [$p<0.05$] compared to the middle and wealthiest terciles in 2010, the year when seed variety patterns are statistically not different between wealth terciles.

Seed input price developments over time are characterized by heavy increases in all wealth terciles between 2007 to 2009 before stagnating at higher level in 2010. Compared to 2007, seed prices increased in 2008, 2009, and 2010, respectively, by 51.1% [$p<0.01$], 88.7% [$p<0.01$], and 100% [$p<0.01$] in the poorest, by 46.3% [$p<0.01$], 80.7% [$p<0.01$], and 70.0% [$p<0.01$] in the middle, and by 43.9% [$p<0.01$], 66.4% [$p<0.01$], and 65.4% [$p<0.01$] in the wealthiest tercile (differences between yearly comparisons for 2008/2009 and 2008/2010 significantly different at the [$p<0.01$] level in all wealth terciles, 2009/2010 yearly comparison [ns] in all wealth terciles).[25]

In accordance with seed input prices, total seed input cost increases are in similar range. In 2008, 2009, and 2010 compared to 2007 increases in total seed input cost reach 57.2% [$p<0.01$], 94.3% [$p<0.01$], and 109.3% [$p<0.01$] in the poorest, 45.5% [$p<0.01$], 76.6% [$p<0.01$], and 57.9% [$p<0.01$] in the middle, and 49.4% [$p<0.01$], 69.9% [$p<0.01$], and 64.0% [$p<0.01$] in the wealthiest tercile (yearly comparisons significantly different at the [$p<0.01$] level in all wealth terciles for 2008/2009 and significantly different in the poorest tercile [$p<0.01$] for 2008/2010, any other yearly comparison [ns]).

Studying fertiliser use next, we first look at fertiliser utilization by household wealth terciles (Table 2-7).

Most households in all wealth terciles apply mineral fertilisers. The share of the poorest households that apply mineral fertilisers is slightly smaller at the beginning of the period but increases over time. While in the poorest tercile 86.4%, 95.6%, 92.0%, and 100% of the households use mineral fertilisers, in the middle tercile 98.9% [$p<0.05$], 100% [ns], 98.7% [ns], and 100% [ns], and in the wealthiest tercile 100% [$p<0.05$], 100% [ns], 100% [$p<0.05$], and 100% [ns] of the households use mineral fertilisers from 2007 to 2010, respectively. Differences in the share of households that use mineral fertilisers between the middle and wealthiest terciles are never statistically significantly different from zero in any of the years. Differences between years are only significantly different in the poorest tercile, where the share of households using mineral fertilisers increases between 2007/2008 [$p<0.1$], 2007/2010 [$p<0.01$], and 2009/2010 [$p<0.1$]. Differences in the middle and wealthiest terciles are not statistically significantly different from zero over time.

[25] Seed input price developments in this paragraph are based on seed input price changes including any changes in changing seed variety choice (for example the switch from LVN10 towards NK varieties). For seed input price developments excluding any changes in seed input mix, seed input prices for LVN10, NK, CP increase on average approximately by 43% in the poorest, 54% in the middle, and 40% in the wealthiest terciles between 2007 and 2010.

The most popular mineral fertilisers types in total fertiliser use are NPK (70.2-76.7%), urea (22.5-28.9%), and to a much smaller extent Potassium and/or rock phosphates (0.5-2%).[26] Use shares of NPK and urea between wealth terciles are not significantly different from zero in any of the years. Potassium and/or phosphorous shares are only significantly different from zero between the poorest (0.6%) and the wealthiest tercile (1.8%, $p<0.05$) in 2010. Shares of NPK and urea in fertiliser use however change in all wealth terciles over time. NPK shares decrease in all wealth terciles slightly from 2007 to 2010, in the poorest from 76.0% to 71.6% [$p<0.05$], in the middle from 76.7% to 69.7% [$p<0.01$], and in the wealthiest tercile from 74.5% to 70.2% [$p<0.01$], respectively. Urea shares increase in all wealth terciles accordingly from 2007 to 2010, in the poorest from 22.5% to 27.8% [$p<0.1$], in the middle from 22.8% to 28.9% [$p<0.01$], and in the wealthiest tercile from 24.3% to 28.0% [$p<0.05$], respectively. Potassium and phosphorous shares stay about the same.

Studying the total fertiliser quantity use, large differences between the poorest and the middle as well as wealthiest households are apparent though (Table 2-8).

From 2007 to 2010, households in the poorest tercile apply significantly lower quantities of fertiliser, i.e. 616, 786, 779, and 880 kg/ha, than the middle tercile (compared to the poorest), i.e. 1060, 1152, 1169, and 1136 kg/ha (72.1% [$p<0.01$], 46.5% [$p<0.01$], 50.0% [$p<0.01$], and 29.1% [$p<0.01$]) and the wealthiest tercile (compared to the poorest), i.e. 1047, 1144, 1174, and 1092 kg/ha (70.1% [$p<0.01$], 45.5% [$p<0.01$], 50.7% [$p<0.01$], and 24.1% [$p<0.01$]), respectively. Differences in fertiliser quantity use between the middle and the wealthiest households are not significantly different from zero in any of the years. In terms of fertiliser use over time, differences are statistically significant in the poorest tercile in 2007/2008 (27.7%, $p<0.01$), 2007/2009 (26.5%, $p<0.01$), and 2007/2010 (42.9%, $p<0.01$), in the middle tercile in 2007/2008 (8.7%, $p<0.01$), 2007/2009 (10.3%, $p<0.01$) but not in 2010 (7.1%, ns), and in the wealthiest tercile in 2007/2008 (9.2%, $p<0.01$), 2007/2009 (12.1%, $p<0.01$) but not in 2010 (4.2%, ns) (any other remaining comparisons by year [ns]).

Comparing fertiliser use quantities of households to general fertiliser recommendations of 1040 to 1200 kg/ha for maize in the Northwest region (Staal et al., 2014: 80), the data shows that on average the poorest households reach 55.0%, 70.2%, 69.6%, 78.6%, the middle 94.6%, 102.9%, 104.4%, 101.4%, and the wealthiest 93.5%, 102.1%, 104.8%, 97.5% of the recommended fertiliser quantity from 2007 to 2010, respectively.[27]

---

[26] Use shares [%] are computed from all households using mineral fertilisers.

[27] Percentages are computed as: average fertiliser quantity applied (kg/ha) by each wealth tercile and year divided by ½*(1040 kg/ha + 1200 kg/ha) of the recommended total fertiliser quantity of 1040-1220 kg/ha for the Northwest region of the Northern Uplands (Staal et al., 2014: 74 & 80).

Table 2-7: Fertiliser utilization by wealth tercile 2007-2010[1)]

	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
Mean (SD)	**Share HH that use fertiliser [%]**				**Share NPK, if fertiliser is used [%][2)]**				**Share urea, if fertiliser is used [%][2)]**				**Share potassium/phosphorous, if fertiliser is used [%][2)]**			
All HH	95.2	98.5	96.9	100.0	74.3 (14.9)	75.1 (12.5)	71.2 (11.4)	70.5 (11.9)	24.0 (13.9)	24.2 (12.3)	27.8 (11.0)	28.2 (11.6)	1.7 (4.4)	0.6 (2.5)	1.0 (3.5)	1.3 (3.8)
N	[269]	[267]	[259]	[263]	[249]	[248]	[239]	[263]	[249]	[248]	[239]	[263]	[249]	[248]	[239]	[263]
Tests across years[3,4)]	07/08** - 07/10***	- -	09/10*		- 07/09** 07/10***	08/09*** 08/10***	-		- 07/09*** 07/10***	09/10*** 08/10***	-		07/08*** 07/09** -	- -	-	
Poorest (W1)	86.4	95.6	92.0	100.0	76.0 (19.4)	74.3 (15.7)	71.1 (12.6)	71.6 (13.5)	22.5 (18.2)	25.2 (15.3)	28.3 (12.6)	27.8 (13.5)	1.5 (5.2)	0.5 (2.6)	0.6 (2.6)	0.6 (2.1)
N	[88]	[90]	[88]	[87]	[69]	[89]	[77]	[87]	[69]	[89]	[77]	[87]	[69]	[89]	[77]	[87]
Tests across years[3,4)]	07/08* - 07/10***	- -	09/10*		- - 07/10**	- -	-		- - 07/10*	- -	-		- - -	- -	-	
Middle (W2)	98.9	100.0	98.7	100.0	73.6 (11.0)	76.7 (9.8)	71.7 (11.0)	69.7 (9.7)	24.8 (9.8)	22.8 (9.6)	26.9 (9.6)	28.9 (8.9)	1.6 (4.1)	0.6 (2.4)	1.4 (4.5)	1.4 (4.4)
N	[88]	[84]	[79]	[81]	[87]	[80]	[76]	[81]	[87]	[80]	[76]	[81]	[87]	[80]	[76]	[81]
Tests across years[3,4)]	- - -	- -	-		- - 07/10*	08/09*** 08/10***	-		- - 07/10***	08/09** 08/10***	-		07/08* - -	- -	-	
Wealthiest (W3)	100.0	100.0	100.0	100.0	73.7 (14.3)	74.5 (11.4)	70.8 (10.6)	70.2 (12.1)	24.3 (13.5)	24.7 (11.4)	28.3 (10.8)	28.0 (11.8)	2.0 (4.1)	0.8 (2.5)	1.0 (3.1)	1.8 (4.2)
N	[93]	[93]	[92]	[95]	[93]	[88]	[86]	[95]	[93]	[88]	[86]	[95]	[93]	[88]	[86]	[95]
Tests across years[3,4)]	- - -	- -	-		- - 07/10*	08/09** 08/10***	-		- 07/09* 07/10**	08/09** 08/10**	-		- - -	- 09/10*	-	
Tests by wealth tercile[3,5)]	W1/2*** W1/3*** -	- - -	- W1/3** -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- W1/3** -

Note:

1) Percentages may not add up to 100% due to rounding.
2) Descriptives do not include the data of seven (2007), fifteen (2008), and twelve (2009) households with missing values for mineral fertiliser use shares as well as the data of households that do not use mineral fertilisers.
3) Level of error probability: [***] p<0.01, [**] p<0.05, [*] p<0.1, [-] not significantly different from zero.
4) Symmetry (mid-p) tests // repeated-measurements ANOVA followed by paired t-tests // Skillings-Mack-test followed by sign-(rank)-tests for comparisons between years within wealth terciles. Multiple comparisons between years Bonferroni-corrected.
5) $\chi 2$- (Fisher's exact) tests // ANOVA followed by unpaired t-tests // Kruskal-Wallis-test followed by Mann-Whitney-tests for comparisons between wealth terciles within years. Multiple comparisons between wealth terciles Bonferroni-corrected.

Source: Own data

Table 2-8: Fertiliser input by wealth tercile 2007-2010[1)]

	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
Mean (SD)	**Fertiliser input [kg/ha]**				**Fertiliser prices as paid [000 VND/kg]**				**Total fertiliser input cost [000 VND/ha]**				**Share fertiliser input cost in total input cost [%]**				**Total input cost [000VND/ha]**			
All HH	**910 (603)**	**1,026 (581)**	**1,038 (622)**	**1,035 (542)**	**3.80 (1.04)**	**4.90 (1.06)**	**5.16 (0.90)**	**5.15 (0.79)**	**3,360 (2,302)**	**4,899 (2,828)**	**5,235 (3,053)**	**5,273 (2,722)**	**73.37 (19.81)**	**75.11 (14.64)**	**71.99 (17.09)**	**75.29 (11.87)**	**4,236 (2,564)**	**6,216 (3,058)**	**6,808 (3,376)**	**6,814 (2,968)**
[%] Δ to poorest	47.82	30.47	33.28	17.64	-6.55	-7.72	-5.04	-5.05	42.90	22.30	27.10	10.48	11.72	6.86	9.23	5.42	33.57	17.40	19.16	4.99
[%] Δ to 2007	-	12.71	14.02	13.72	-	29.00	35.61	35.46	-	45.81	55.82	56.95	-	2.37	-1.88	2.62	-	46.75	60.71	60.86
N	[269]	[267]	[259]	[263]	[256]	[263]	[251]	[263]	[269]	[267]	[259]	[263]	[269]	[267]	[259]	[263]	[269]	[267]	[259]	[263]
Tests across years[2,3)]	07/08*** 07/09*** 07/10***	- -	-		07/08*** 07/09*** 07/10***	08/09*** 08/10***	-		07/08*** 07/09*** 07/10***	- 08/10**	-		07/08*** 07/09*** -	- -	-		07/08*** 07/09*** 07/10***	- 08/10***	-	
Poorest (W1)	**616 (527)**	**786 (595)**	**779 (587)**	**880 (495)**	**4.07 (1.23)**	**5.31 (1.08)**	**5.43 (1.04)**	**5.42 (0.88)**	**2,351 (1,898)**	**4,006 (2,942)**	**4,119 (3,141)**	**4,773 (2,705)**	**61.66 (27.74)**	**68.24 (20.09)**	**62.76 (23.25)**	**69.87 (16.25)**	**3,171 (2,050)**	**5,295 (3,030)**	**5,713 (3,439)**	**6,490 (2,866)**
[%] Δ to 2007	-	27.70	26.46	42.89	-	30.63	33.45	33.33	-	70.38	75.20	103.01	-	6.59	1.11	8.22	-	66.96	80.15	104.64
N	[88]	[90]	[88]	[87]	[76]	[86]	[81]	[87]	[88]	[90]	[88]	[87]	[88]	[90]	[88]	[87]	[88]	[90]	[88]	[87]
Tests across years[2,3)]	07/08*** 07/09*** 07/10***	- -	-		07/08*** 07/09*** 07/10***	- -	-		07/08*** 07/09*** 07/10***	- 08/10***	-		07/08*** - -	- -	-		07/08*** 07/09*** 07/10***	- 08/10***	-	
Middle (W2)	**1,060 (672)**	**1,152 (596)**	**1,169 (639)**	**1,136 (559)**	**3.62 (0.76)**	**4.64 (0.89)**	**5.00 (0.75)**	**5.04 (0.66)**	**3,836 (2,633)**	**5,319 (2,832)**	**5,793 (3,124)**	**5,706 (2,841)**	**78.13 (12.44)**	**78.16 (9.01)**	**75.32 (12.11)**	**78.45 (7.25)**	**4,766 (3,061)**	**6,671 (3,237)**	**7,434 (3,566)**	**7,173 (3,262)**
[%] Δ to poorest	72.12	46.50	50.04	29.06	-11.09	-12.69	-7.86	-7.07	63.18	32.78	40.65	19.54	16.48	9.92	12.56	8.58	50.27	25.99	30.13	10.52
[%] Δ to 2007	-	8.69	10.25	7.14	-	28.29	38.31	39.36	-	38.64	51.01	48.72	-	0.03	-2.82	0.32	-	39.98	56.00	50.51
N	[88]	[84]	[79]	[81]	[87]	[84]	[78]	[87]	[88]	[84]	[79]	[81]	[88]	[84]	[79]	[81]	[88]	[84]	[79]	[81]
Tests across years[2,3)]	07/08*** 07/09*** -	- -	-		07/08*** 07/09*** 07/10***	08/09** 08/10***	-		07/08*** 07/09*** 07/10***	- -	-		- 07/09** -	08/09* -	-		07/08*** 07/09*** 07/10***	08/09* 08/10*	-	
Wealthiest (W3)	**1.047 (496)**	**1.144 (477)**	**1.174 (563)**	**1.092 (544)**	**3.76 (1.07)**	**4.76 (1.08)**	**5.04 (0.84)**	**4.99 (0.76)**	**3,863 (2,005)**	**5,384 (2,515)**	**5,823 (2,607)**	**5,363 (2,585)**	**79.95 (8.55)**	**78.99 (9.30)**	**77.95 (7.58)**	**77.57 (8.08)**	**4,742 (2,170)**	**6,697 (2,731)**	**7,316 (2,890)**	**6,804 (2,788)**
[%] Δ to poorest	70.08	45.49	50.72	24.06	-7.65	-10.36	-7.08	-7.97	64.31	34.40	41.38	12.36	18.29	10.75	15.19	7.69	49.52	26.47	28.06	4.84
[%] Δ to 2007	-	9.24	12.07	4.23	-	26.79	34.27	32.87	-	39.36	50.75	38.82	-	-0.96	-2.00	-2.38	-	41.22	54.29	43.49
N	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]	[93]	[93]	[92]	[95]
Tests across years[2,3)]	07/08*** 07/09*** -	- -	-		07/08*** 07/09*** 07/10***	08/09*** 08/10*	-		07/08*** 07/09*** 07/10***	- -	-		- 07/09** -	- -	-		07/08*** 07/09*** 07/10***	08/09** -	-	
Tests by wealth tercile[2,4)]	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2** - -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2* - -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	- - -

Note:
1) Percentages may not add up to 100% due to rounding.
2) Level of error probability: [***] p<0.01, [**] p<0.05, [*] p<0.1, [-] not significantly different from zero.
3) Repeated-measurements ANOVA followed by paired t-tests // Skillings-Mack-test followed by sign-(rank)-tests for comparisons between years within wealth terciles. Multiple comparisons between years Bonferroni-corrected.
4) ANOVA followed by unpaired t-tests // Kruskal-Wallis-test followed by Mann-Whitney-tests for comparisons between wealth terciles within years. Multiple comparisons between wealth terciles Bonferroni-corrected.

Source: Own data

Table 2-9: Fertiliser prices by fertiliser type, payment type, and wealth tercile 2008-2010[1,2,3)]

	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
Mean (SD)	**Share HH that buy NPK on-loan [%]**			**NPK price no-loan [000VND/kg]**			**NPK price on-loan [000VND/kg]**			**Share HH that buy Urea on-loan [%]**			**Urea price no-loan [000VND/kg]**			**Urea price on-loan [000VND/kg]**		
All HHs	**68.27**	**64.52**	**55.13**	**3.46 (0.70)**	**3.50 (0.63)**	**3.46 (0.54)**	**4.03 (0.73)**	**4.14 (0.66)**	**4.24 (0.42)**	**66.81**	**63.79**	**54.30**	**7.37 (1.49)**	**7.45 (1.34)**	**7.60 (0.87)**	**8.47 (1.52)**	**8.75 (1.35)**	**8.75 (0.91)**
[%] Δ to poorest	-20.88	-22.98	-21.88	-3.96	8.40	-2.98	-3.45	-3.20	-0.91	-21.03	-23.23	-21.01	-3.96	8.40	-2.23	-2.73	-2.72	-3.12
[%] Δ loan/no-loan[4,5)]	—	—	—	—	—	—	16.38***	18.49***	22.25***	—	—	—	—	—	—	14.89***	17.45***	15.13***
N	[249]	[248]	[263]	[76]	[84]	[118]	[159]	[152]	[145]	[238]	[243]	[256]	[76]	[84]	[117]	[148]	[147]	[139]
Poorest (W1)	**89.16**	**87.50**	**77.01**	**3.60 (0.49)**	**3.23 (0.47)**	**3.57 (0.39)**	**4.17 (0.74)**	**4.28 (0.83)**	**4.27 (0.50)**	**87.84**	**87.01**	**75.31**	**7.68 (1.05)**	**6.87 (1.00)**	**7.77 (0.90)**	**8.71 (1.55)**	**8.99 (1.70)**	**9.03 (0.94)**
[%] Δ loan/no-loan[4,5)]	—	—	—	—	—	—	15.76**	32.70***	19.70***	—	—	—	—	—	—	13.43*	30.88***	16.18***
N	[83]	[80]	[87]	[9]	[10]	[20]	[69]	[66]	[67]	[74]	[77]	[81]	[9]	[10]	[20]	[60]	[63]	[61]
Middle (W2)	**59.49**	**61.84**	**53.09**	**3.46 (0.71)**	**3.44 (0.46)**	**3.35 (0.29)**	**3.86 (0.73)**	**4.03 (0.49)**	**4.18 (0.33)**	**58.97**	**60.81**	**53.75**	**7.37 (1.51)**	**7.34 (0.98)**	**7.42 (0.81)**	**8.17 (1.52)**	**8.52 (1.01)**	**8.48 (0.94)**
[%] Δ to poorest	-29.66	-25.66	-23.93	-3.94	6.78	-6.19	-7.40	-5.79	-2.31	-28.86	-26.20	-21.56	-3.94	6.78	-4.45	-6.12	-5.24	-6.09
[%] Δ loan/no-loan[4,5)]	—	—	—	—	—	—	11.60**	17.09***	24.64***	—	—	—	—	—	—	10.86**	16.15***	14.19***
N	[79]	[76]	[81]	[30]	[27]	[38]	[45]	[47]	[43]	[78]	[74]	[80]	[30]	[27]	[37]	[44]	[45]	[43]
Wealthiest (W3)	**56.32**	**46.74**	**36.84**	**3.43 (0.74)**	**3.58 (0.73)**	**3.50 (0.67)**	**3.97 (0.67)**	**4.04 (0.47)**	**4.23 (0.32)**	**55.81**	**46.74**	**38.84**	**7.30 (1.58)**	**7.63 (1.55)**	**7.65 (0.89)**	**8.44 (1.45)**	**8.61 (1.00)**	**8.58 (0.66)**
[%] Δ to poorest	-32.83	-40.76	-40.17	-4.94	11.13	-1.94	-4.79	-5.51	-0.93	-30.02	-40.27	-38.47	-4.94	11.13	-1.61	-3.04	-4.20	-4.93
[%] Δ loan/no-loan[4,5)]	—	—	—	—	—	—	15.94***	12.83***	20.93***	—	—	—	—	—	—	15.69***	12.83***	12.27***
N	[87]	[92]	[95]	[37]	[47]	[60]	[45]	[39]	[45]	[86]	[92]	[95]	[37]	[47]	[60]	[44]	[39]	[35]
Tests by wealth terciles[4,6)]	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** W2/3*	- - -	- - -	W1/2** - -	W1/2* - -	- - -	- - -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2** W1/3*** W2/3*	- - -	- - -	- - -	- - -	- - -	W1/2*** W1/3* -

Note:

1) Percentages may not add up to 100% due to rounding.
2) NPK and urea prices are directly reported values in 2010. In 2008 and 2009 values are computed from overall (all households) fertiliser price ratios (2010), households' fertiliser use shares (2008; 2009), and whether households buy fertiliser on-loan (2008; 2009).
3) Descriptives do not include data from households a) that do not use NPK/urea, b) with missing values for "fertiliser use shares", and c) missing values "whether NPK/urea fertiliser is bought on-loan".
4) Level of error probability: [***] p<0.01, [**] p<0.05, [*] p<0.1, [-] not significantly different from zero. [—] Does not apply.
5) Unpaired t-test // Mann-Whitney test.
6) $\chi 2$ – (Fisher's exact) tests // ANOVA followed by unpaired t-tests // Kruskal-Wallis-test followed by Mann-Whitney-tests for comparisons <u>between wealth terciles</u> within years. Multiple comparisons between wealth terciles Bonferroni-corrected.

Source: Own data

However, the data also shows that a noticeable part of households in all wealth terciles possibly underuses as well as overuses fertiliser (not considering variety choice and soil-property based differences). In the poorest tercile a higher share of households underuses fertilisers by more than 25% below average fertiliser recommendation (i.e. 69%, 68%, 64%, 51%) than in the middle (50% [p<0.05]; 39% [p<0.01]; 34% [p<0.01]; 27% [p<0.01]) and the wealthiest terciles (39% [p<0.01]; 28% [p<0.01]; 28% [p<0.01]; 33% [p<0.05]) from 2007 to 2010, respectively. Differences between the middle and wealthiest tercile are not significantly different from zero. Overuse of fertilisers by more than 25% above the average fertiliser recommendation is in the beginning of the period less pronounced in the poorest tercile but evens out over time, reaching 7%, 16%, 13%, 11% in the poorest compared to 20% [p<0.05], 23% [ns], 24% [ns], 21% [ns] in the middle, and 19% [p<0.05], 24% [ns], 29% [p<0.05], 17% [ns] in the wealthiest terciles from 2007 to 2010, respectively. Differences between the middle and wealthiest terciles are not statistically different from zero.

Like with seed input, a high share of households buy fertiliser input (i.e. NPK, urea) by on-loan arrangements, the poorest households again significantly more often than the middle and wealthiest terciles (Table 2-9).[28] From 2008 to 2010, 89.2-75.3% in the poorest tercile buy NPK/urea on-loan compared to 61.8-53.1% in the middle and 56.3-36.8% in the wealthiest tercile. Differences are significantly different in the poorest compared to middle and wealthiest terciles for NPK and urea in all years [p<0.01], between the middle and wealthiest tercile they are not statistically significantly different in 2008 and 2009 but significantly different in 2010 [p<0.1]. Further, the number of households that purchase fertiliser on-loan decreases in the poorest and wealthiest terciles and remains stable [ns] in the middle tercile. In the poorest tercile (and contrary to seed input purchased on-loan) households could reduce their dependency on fertiliser purchases on-loan slightly from 89% to 77% [p<0.05] for all fertilisers, from 89% to 77% for NPK [p<0.05], and from 88% to 75% [ns] for urea from 2008 to 2010, respectively. In the wealthiest terciles (and in line with reducing their dependency on purchasing seed input on-loan) dependency for fertiliser input purchased on-loan decreases from 56% to 37% [p<0.05] for all fertilisers, from 56% to 37% [p<0.05] for NPK, and from 56% to 39% for urea [p<0.05] from 2008 to 2010, respectively (data is not shown separately in Table 2-9).

Considering differences in fertiliser input prices per kg, separated by type of fertiliser (NPK, urea) and payment arrangement (directly purchased, on-loan), fertiliser prices are only weakly dependent on wealth tercile (Table 2-9). While differences between direct and on-loan prices of NPK/urea mount to 17.4% [p<0.01] on average,[29] differences between wealth terciles for

[28] We do not compare direct/on-loan prices of potassium and phosphorus fertilisers by wealth tercile additionally here since the number of households that purchased potassium or phosphorus fertilisers is small, i.e. between 0-16 for direct prices and 0-7 for on-loan prices per wealth tercile and year.

[29] Unweighted sum of yearly differences between direct/on-loan NPK and urea price comparisons; [p<0.01] refers to the level of error probability of each yearly direct/on-loan NPK and urea price comparison.

NPK/urea prices separated by payment arrangement are less pronounced. Direct prices for NPK and urea are rarely significantly different between wealth terciles in all years (except the comparison between the poorest/middle tercile [p<0.05] in 2010). On-loan fertiliser prices are only statistically significantly different for NPK between the poorest/middle (7.4%, p<0.1) in 2007 and for urea between the poorest/middle (6.1%, p<0.05) and the poorest/wealthiest (4.9%, p<0.1) in 2010.

Contrary to seed input prices, distance-related measures are mostly correlated with fertiliser input prices. Distance to paved road is positively correlated (Pearson correlation coefficient) to all types of fertiliser prices, i.e. to NPK purchased directly (0.16, p<0.01), urea purchased directly (0.12, p<0.05), NPK purchased on-loan (0.19, p<0.01), and urea purchased on-loan (0.14, p<0.01). Correlations between distance to provincial capital (Yen Chau) and direct NPK and urea prices are not statistically significant but positive and statistically significant for NPK on-loan (0.23, p<0.01) and urea on-loan (0.17, p<0.01) prices. Distance to closest market is mostly not correlated with fertiliser prices and if so then negatively (i.e. between distance to closest market and urea on-loan prices (-0.14, p<0.05), most likely because of a negative relationship between distance to closest market and distance to paved road (i.e. -0.15, p<0.01). Any other correlations between distance to closest market and fertiliser prices are not significantly different from zero (data not separately shown here).

In effect, final fertiliser prices, that is average fertiliser prices paid by the household after choice of fertiliser mix (which is statistically not different between wealth terciles), whether the households purchased fertilisers directly or on-loan, and distance-related effects (for those fertiliser prices which are correlated to distance through household wealth), the poorest households pay substantially higher effective fertiliser prices than the middle and the wealthiest households in all years (Table 2-8). From 2007 to 2010, effective fertiliser prices paid per kg of fertiliser used are 11.1% [p<0.05], 12.7% [p<0.01], 7.9% [p<0.01], and 7.1% [p<0.01] higher in the poorest compared to the middle tercile and 7.7% [ns], 10.4% [p<0.01], 7.1% [p<0.01], and 8.0% [p<0.01] higher in the poorest compared to the wealthiest tercile, respectively. Differences in effective fertiliser prices between the middle and wealthiest tercile are not statistically significantly different from zero in any of the years.

Effective fertiliser prices paid increase tremendously and in similar range in all wealth terciles over time, with the strongest price raises between 2007 and 2008 before stagnating at higher levels in 2009 and 2010. Compared to 2007, fertiliser price increases reach 30.6% [p<0.01], 33.5% [p<0.01], and 33.3% [p<0.01] in the poorest, 28.3% [p<0.01], 38.3% [p<0.01], and 39.4% [p<0.01] in the middle, and 26.8% [p<0.01], 34.3% [p<0.01], and 32.9% [p<0.01] in the wealthiest tercile in 2008, 2009, and 2010, respectively (differences for comparisons between

Unweighted (weighted) yearly difference between direct/on-loan prices were 19.0% (18.8%, p<0.01) for NPK and 15.8% (15.3%, p<0.01) for urea between 2008 and 2010, respectively.

2008/2009, 2008/2010, 2009/2010 are in the poorest [ns], middle [p<0.05; p<0.01; ns], wealthiest [p<0.01; p<0.1; ns]).[30]

In contrary to seed price development that is similar between wealth terciles over time, the growth of fertiliser cost encountered by households is additionally influenced by the extent of changes in fertiliser quantity applied. In consequence, the poorest tercile experiences the highest increases in fertiliser costs from 2007 to 2010, while at the same time absolute fertiliser cost differences between wealth terciles decline. In the years 2008, 2009, and 2010 compared to 2007, fertiliser cost growth reaches (at increasing fertiliser use rates) in the poorest tercile 70.4% [p<0.01], 75.2% [p<0.01], and 103.0% [p<0.01] (27.7%, 26.5%, and 42.9%), in the middle tercile 38.6% [p<0.01], 51.0% [p<0.01], and 48.7% [p<0.01] (8.7%, 10.3%, and 7.1%), and in the wealthiest tercile 39.4% [p<0.01], 50.6% [p<0.01], and 38.8% [p<0.01] (9.2%, 12.1%, and 4.2%), respectively (yearly fertiliser cost differences between 2008/2010 are significantly different in the poorest tercile [p<0.01] only, any other yearly comparisons in any wealth tercile [ns]). Consequently, in 2008, 2009, and 2010 compared to 2007, absolute fertiliser cost differences between the poorest and the other terciles decline, from the poorest tercile having lower fertiliser cost compared to the middle of 63.2% [p<0.01], 32.8% [p<0.01], 40.7% [p<0.01], and 19.5% [p<0.1] and compared to the wealthiest tercile of 64.3% [p<0.01], 34.4% [p<0.01], 41.4% [p<0.01], and 12.4% [ns], respectively. Differences in absolute fertiliser cost between the middle and wealthiest terciles are never statistically significantly different from zero in any years.

The same picture holds when the development of total input costs is considered. Accounting not only for the direct changes in input prices but for changes in seed variety patterns (in all wealth terciles in different speed towards the same seed variety mix in 2010), fertiliser mix (in all wealth terciles equally strong towards more urea), fertiliser quantity applied (stronger in the poorest tercile), as well as in the share of households that purchased input on-loan-based arrangements (i.e. stable in the poorest and middle terciles and decreasing in the wealthiest tercile), total input cost increase the most in the poorest tercile, and absolute differences in total input cost between wealth terciles decrease. In 2008, 2009, 2010 compared to 2007, total input cost increase by 70.0% [p<0.01], 80.2% [p<0.01], 104.6% [p<0.01] in the poorest, by 40.0% [p<0.01], 56.0% [p<0.01], 50.5% [p<0.01] in the middle, and by 41.2% [p<0.01], 54.3% [p<0.01], 43.5% [p<0.01] in the wealthiest tercile, respectively (comparisons between 2008/2009, 2008/2010, 2009/2010 are significantly different in the poorest [ns; p<0.01; ns], middle [p<0.1; p<0.1; ns], and wealthiest tercile [p<0.05; ns; ns]). At the same time, the gap in total input cost from 2007 to 2008, 2009, and 2010 decreases from 50.3% [p<0.01] to 26.0% [p<0.01], 30.1% [p<0.01], and 10.5% [ns] lower total input cost in the poorest compared to

[30] Fertiliser input price developments in this paragraph are based on fertiliser input price changes including any changes in fertiliser mix (and possibly fertiliser composition). For fertiliser input price developments excluding any changes in fertiliser mix, NPK/urea prices increase on average approximately by 30% in the poorest, 34% in the middle, and 29% in the wealthiest tercile between 2007 and 2010.

the middle tercile and from 49.5% [p<0.01], 26.5% [p<0.01], 28.1% [p<0.01], and 4.8% [ns] lower input cost in the poorest compared to the wealthiest tercile, respectively. Differences between the middle and wealthiest terciles are never statistically significantly different from zero in any year.

Input cost distribution between seed and fertiliser cost shares roughly stay the same with minor variations only (Table 2-5 & Table 2-8). Fertilisers cost shares in total input cost (seed cost are the remainder adding up to 100%) reach in the poorest tercile 61.7%, 68.2%, 62.8%, and 69.9% (yearly comparisons 2007/2008 [p<0.01]; otherwise [ns]), in the middle tercile 78.1%, 78.2%, 75.3%, and 78.5% (yearly comparisons 2007/2009 [p<0.05]; 2008/2009 [p<0.1]; otherwise [ns]), and in the wealthiest tercile 80.0%, 79.0%, 78.0%, 77.6% (yearly comparisons 2007/2009 [p<0.05]; otherwise [ns]) between 2007 and 2010, respectively. Differences in fertiliser cost shares between the poorest/middle and poorest/wealthiest are statistically significantly different [p<0.01] in all years, differences between middle/wealthiest are never statistically significantly different from zero in any of the years.

Studying maize output, maize output prices, and maize income by wealth tercile shows that the poorest households reach significantly lower yields, similar maize output prices, and lower net maize income per hectare than the middle and wealthiest terciles. Departing from this trend is the year 2010 when a wide-ranging drought affected all wealth terciles in the area (Table 2-10).

From 2007 to 2009, maize yields are the lowest in the poorest tercile reaching 6.8 t/ha in 2007, 6.4 t/ha in 2008, and 6.0 t/ha in 2009. Maize yields in the middle and wealthiest terciles are significantly higher compared to the poor. In the middle tercile maize yields reach (difference to the poorest) 7.5 t/ha (+27.9%, p<0.01) in 2007, 7.9 t/ha (+24.4%, p<0.01) in 2008, and 7.5 t/ha (+25.3%, p<0.05) in 2009. In the wealthiest tercile maize yields reach (difference to the poorest) 7.8 t/ha (+33.2%, p<0.01) in 2007, 8.2 t/ha (+28.4%, p<0.01) in 2008, and 8.1 t/ha (36.1%, p<0.01) in 2009. Differences between the middle and wealthiest terciles are not significantly different from zero in any of the years between 2007 and 2009. In 2010, the drought year, yields are lower and not significantly different from zero between any of the wealth terciles, reaching 5.6, 6.4 (+13.8%), and 6.4 (+13.3%) t/ha in the poorest, middle, and wealthiest terciles, respectively.

Table 2-10: Maize output by wealth tercile 2007-2010

	2007	2008	2009	2010	07-10	2007	2008	2009	2010	07-10	2007	2008	2009	2010	07-10	2007	2008	2009	2010	07-10
Mean (SD)	**Maize yield [t/ha]**				**CV**	**Maize output price as received [000VND/kg]**				**CV**	**Maize gross margin, nominal [000VND/ha]**				**CV**	**Maize gross margin, deflated [000VND/ha]**				**CV**
All HH	**7.04 (2.79)**	**7.48 (2.72)**	**7.19 (3.56)**	**6.23 (2.50)**	**26.71 (14.56)**	**3.16 (0.46)**	**2.98 (0.42)**	**3.58 (0.58)**	**5.04 (0.88)**	**25.90 (8.73)**	**18,184 (8,513)**	**16,205 (7,434)**	**18,838 (11,073)**	**24,350 (11,369)**	**40.65 (20.64)**	**18,184 (8,513)**	**13,253 (6,080)**	**14,404 (8,467)**	**17,198 (8,029)**	**39.49 (18.94)**
[%] Δ to poorest	20.60	17.56	20.52	9.05	-10.62	4.33	4.19	-3.33	-2.39	-9.42	24.71	24.46	15.58	8.04	-13.64	24.71	24.46	15.58	8.04	-11.70
[%] Δ to 2007	-	6.35	2.15	-11.53	-	-	-5.52	13.54	59.80	-	-	-10.88	3.60	33.91	-	-	-27.12	-20.78	-5.42	-
N	[269]	[267]	[259]	[263]	[276]	[269]	[267]	[259]	[263]	[276]	[269]	[267]	[259]	[263]	[276]	[269]	[267]	[259]	[263]	[276]
Test across years[1,2]	07/08*** - 07/10***	08/09*** 08/10***	09/10***			07/08*** 07/09*** 07/10***	08/09*** 08/10***	09/10***			07/08*** - 07/10***	- 08/10***	09/10***			07/08*** 07/09*** -	- 08/10***	09/10***		
Poorest (W1)	**5.84 (2.35)**	**6.37 (2.57)**	**5.96 (3.35)**	**5.71 (2.70)**	**29.88 (15.87)**	**3.02 (0.57)**	**2.86 (0.35)**	**3.71 (0.71)**	**5.17 (0.98)**	**28.60 (9.57)**	**14,581 (6,841)**	**13,020 (6,259)**	**16,298 (10,958)**	**22,537 (12,298)**	**47.08 (23.45)**	**14,581 (6,841)**	**10,648 (5,119)**	**12,463 (8,379)**	**15,918 (8,686)**	**44.72 (21.31)**
[%] Δ to 2007	-	9.10	2.21	-2.16	-	-	-5.39	22.52	70.79	-	-	-10.70	11.78	54.57	-	-	-26.97	-14.53	9.17	-
N	[88]	[90]	[88]	[87]	[95]	[88]	[90]	[88]	[87]	[95]	[88]	[90]	[88]	[87]	[95]	[88]	[90]	[88]	[87]	[95]
Test across years[1,2]	07/08** - -	- -	-			07/08** 07/09*** 07/10***	08/09*** 08/10***	09/10***			- - 07/10***	- 08/10***	09/10***			07/08*** 07/09** -	- 08/10***	09/10***		
Middle (W2)	**7.46 (3.13)**	**7.92 (2.96)**	**7.47 (3.28)**	**6.50 (2.60)**	**24.93 (13.53)**	**3.22 (0.38)**	**2.99 (0.22)**	**3.46 (0.42)**	**4.90 (0.64)**	**23.68 (7.62)**	**19,419 (9,157)**	**17,026 (7,179)**	**18,576 (9,981)**	**24,607 (11,343)**	**38.44 (19.32)**	**19,419 (9,157)**	**13,924 (5,871)**	**14,204 (7,632)**	**17,379 (8,011)**	**37.85 (18.33)**
[%] Δ to poorest	27.90	24.39	25.27	13.79	-16.55	6.37	4.46	-6.53	-5.18	-17.21	33.18	30.77	13.98	9.18	-18.35	33.18	30.77	13.98	9.18	-15.35
[%] Δ to 2007	-	6.11	0.11	-12.96	-	-	-7.09	7.67	52.24	-	-	-12.32	-4.34	26.71	-	-	-28.30	-26.85	-10.51	-
N	[88]	[84]	[79]	[81]	[86]	[88]	[84]	[79]	[81]	[86]	[88]	[84]	[79]	[81]	[86]	[88]	[84]	[79]	[81]	[86]
Test across years[1,2]	07/08*** - -	- 08/10**	09/10**			07/08*** 07/09*** 07/10***	08/09*** 08/10***	09/10***			07/08** - 07/10***	- 08/10***	09/10*** -			07/08*** 07/09*** -	- 08/10***	09/10**		
Wealthiest (W3)	**7.77 (2.46)**	**8.17 (2.29)**	**8.12 (3.69)**	**6.47 (2.16)**	**25.13 (13.67)**	**3.22 (0.39)**	**3.09 (0.58)**	**3.57 (0.53)**	**5.05 (0.94)**	**25.23 (8.15)**	**20,423 (8,283)**	**18,547 (7,702)**	**21,491 (11,577)**	**25,790 (10,352)**	**36.24 (17.12)**	**20,423 (8,283)**	**15,168 (6,299)**	**16,433 (8,852)**	**18,215 (7,312)**	**35.73 (15.73)**
[%] Δ to poorest	33.18	28.39	36.08	13.30	-15.88	6.48	7.99	-3.76	-2.18	-11.79	40.07	42.44	31.86	14.43	-23.03	40.07	42.44	31.86	14.43	-20.10
[%] Δ to 2007	-	5.18	4.44	-16.77	-	-	-4.05	10.74	56.89		-	-9.19	5.23	26.28	-	-	-25.73	-19.54	-10.81	-
N	[93]	[93]	[92]	[95]	[95]	[93]	[93]	[92]	[95]	[95]	[93]	[93]	[92]	[95]	[95]	[93]	[93]	[92]	[95]	[95]
Test across years[1,2]	07/08** - 07/10***	- 08/10***	09/10***			07/08* 07/09*** 07/10***	08/09*** 08/10***	09/10***			07/08*** - 07/10***	- 08/10***	09/10***			07/08*** 07/09*** -	- 08/10***	-		
Tests by wealth terciles[1,3]	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/2** W1/3*** -	- - -	W1/2* W1/3* -	W1/2** W1/3** -	- W1/3*** -	W1/2** - -	- - -	W1/2*** W1/3** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	W1/3*** -	- - -	W1/2** W1/3*** -	W1/2*** W1/3*** -	W1/2*** W1/3*** -	- W1/3*** -	- - -	W1/2** W1/3***

Note:
1) Level of error probability: [***] p<0.01, [**] p<0.05, [*] p<0.1, [-] not significantly different from zero.
2) Repeated-measurements ANOVA followed by paired t-tests // Skillings-Mack-test followed by sign-(rank)-tests for comparisons between years within wealth terciles. Multiple comparisons between years Bonferroni-corrected.
3) ANOVA followed by unpaired t-tests // Kruskal-Wallis-test followed by Mann-Whitney-tests for comparisons between wealth terciles within years. Multiple comparisons between wealth terciles Bonferroni-corrected.

Source: Own data

Table 2-11: Maize output prices by variety and wealth tercile 2007-2010

	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
Mean (SD)	**Maize output price LVN10 [000VNDkg-1]**				**Maize output price NK varieties [000VNDkg-1]**				**Maize output price CP varieties [000VNDkg-1]**				**Maize output price Other varieties [000VNDkg-1]**			
All HH	**3.08 (0.41)**	**3.01 (0.65)**	**3.59 (0.56)**	**4.71 (0.60)**	**3.43 (0.36)**	**3.00 (0.30)**	**3.61 (0.55)**	**5.12 (0.77)**	**3.20 (0.33)**	**3.06 (0.21)**	**3.52 (0.50)**	**5.10 (0.67)**	**3.10 (0.60)**	**2.93 (0.31)**	**3.57 (0.63)**	**5.05 (1.10)**
[%] Δ to poorest	5.02	6.85	-1.71	-5.95	-3.49	0.94	-0.95	-2.71	1.56	1.11	-12.39	-6.56	8.59	3.96	-4.13	1.81
[%] Δ to 2007	-	-2.21	16.65	53.08	-	-12.39	5.17	49.36	-	-4.56	9.89	59.20	-	-5.32	15.50	63.02
N	[132]	[74]	[61]	[34]	[46]	[67]	[77]	[130]	[31]	[23]	[23]	[15]	[60]	[103]	[98]	[84]
Tests across years[1,2)]	07/08** 07/09*** 07/10***	08/09*** 08/10***	09/10***		07/08*** - 07/10***	08/09*** 08/10***	09/10***		- 07/09* 07/10***	08/09*** 08/10***	09/10***		- 07/09*** 07/10***	08/09*** 08/10***	09/10***	
Poorest (W1)	**2.93 (0.51)**	**2.82 (0.38)**	**3.65 (0.62)**	**5.01 (0.66)**	**3.55 (0.22)**	**2.98 (0.26)**	**3.64 (0.61)**	**5.26 (1.03)**	**3.16 (0.32)**	**3.03 (0.17)**	**4.02 (0.48)**	**5.46 (0.58)**	**2.85 (0.70)**	**2.82 (0.38)**	**3.73 (0.83)**	**4.96 (1.02)**
[%] Δ to 2007	-	-3.88	24.65	70.93	-	-16.24	2.47	48.15	-	-4.14	27.39	73.03	-	-1.11	30.81	73.88
N	[44]	[32]	[23]	[7]	[13]	[20]	[19]	[50]	[9]	[4]	[5]	[5]	[22]	[34]	[41]	[25]
Tests across years[1,2)]	- 07/09*** 07/10***	08/09*** 08/10***	09/10***		07/08*** - 07/10***	08/09*** 08/10***	09/10***		- 07/09*** 07/10***	08/09** 08/10***	09/10**		- 07/09*** 07/10***	08/09*** 08/10***	09/10***	
Middle (W2)	**3.12 (0.28)**	**3.07 (0.13)**	**3.51 (0.53)**	**4.59 (0.65)**	**3.40 (0.22)**	**3.07 (0.26)**	**3.53 (0.38)**	**5.00 (0.61)**	**3.22 (0.37)**	**2.95 (0.15)**	**3.30 (0.38)**	**4.98 (0.75)**	**3.30 (0.55)**	**2.93 (0.22)**	**3.44 (0.39)**	**4.91 (0.64)**
[%] Δ to poorest	6.53	8.98	-3.87	-8.35	-4.32	3.27	-3.16	-5.00	1.91	-2.64	-17.91	-8.88	15.80	3.85	-7.66	-0.96
[%] Δ to 2007	-	-1.66	12.48	47.07	-	-9.59	3.72	47.11	-	-8.42	2.61	54.70	-	-11.31	4.31	48.72
N	[42]	[16]	[16]	[13]	[12]	[19]	[21]	[33]	[11]	[10]	[8]	[4]	[23]	[39]	[34]	[31]
Tests across years[1,2)]	- 07/09* 07/10***	08/09** 08/10***	09/10***		07/08*** - 07/10***	08/09*** 08/10***	09/10***		- - 07/10*	- 08/10*	09/10***		07/08** - 07/10***	08/09** 08/10***	09/10***	
Wealthiest (W3)	**3.18 (0.36)**	**3.21 (0.99)**	**3.58 (0.53)**	**4.67 (0.51)**	**3.37 (0.47)**	**2.98 (0.34)**	**3.63 (0.60)**	**5.05 (0.49)**	**3.23 (0.32)**	**3.20 (0.20)**	**3.45 (0.45)**	**4.89 (0.68)**	**3.14 (0.38)**	**3.06 (0.31)**	**3.50 (0.45)**	**5.28 (1.51)**
[%] Δ to poorest	8.46	13.79	-1.93	-6.69	-5.18	0.04	-0.18	-3.98	2.49	5.79	-14.18	-10.47	10.12	8.57	-6.26	6.48
[%] Δ to 2007	-	1.00	12.71	47.06	-	-11.63	7.87	50.03	-	-1.05	6.68	51.15	-	-2.49	11.35	66.13
N	[46]	[26]	[22]	[14]	[21]	[28]	[37]	[47]	[11]	[9]	[10]	[6]	[15]	[30]	[23]	[28]
Tests across years[1,2)]	- 07/09** 07/10***	08/09*** 08/10***	09/10***		07/08*** - 07/10***	08/09*** 08/10***	09/10***		- - 07/10***	- 08/10***	09/10***		- 07/09* 07/10***	- 08/10***	09/10***	
Test by wealth tercile[1,3)]	W1/2* W1/3** -	W1/2*** W1/3** -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - W2/3**	W1/2** W1/3* -	- - -	W1/2** - -	- W1/3*** -	- - -	- - -

Note:
1) Level of error probability: [***] p<0.01, [**] p<0.05, [*] p<0.1, [-] not significantly different from zero.
2) Repeated-measurements ANOVA followed by paired t-tests // Skillings-Mack-test followed by sign-(rank)-tests for comparisons between years within wealth terciles. Multiple comparisons between years Bonferroni-corrected.
3) ANOVA followed by unpaired t-tests // Kruskal-Wallis-test followed by Mann-Whitney-tests for comparisons between wealth terciles within years. Multiple comparisons between wealth terciles Bonferroni-corrected.

Source: Own data

In 2008, 2009, and 2010 compared to 2007, the respective yield developments reach in the poorest tercile plus 9.1% [p<0.05], plus 2.2% [ns], and -2.2% [ns] (any other yearly comparisons [ns]), in the middle tercile plus 6.1% [p<0.01], plus 0.1% [ns], and -13.0% [ns] (yearly comparisons between 2008/2010, 2009/2010 [p<0.05]; otherwise [ns]), and in the wealthiest tercile plus 5.2% [p<0.05], plus 4.4% [ns], and -16.8% [p<0.01] (yearly comparisons between 2008/2010, 2009/2010 [p<0.01]; otherwise [ns]). The coefficient of variation of maize yields[31] over the 2007 to 2010 period is however significantly higher in the poorest (29.9%) than in the middle (24.9%, p<0.1) and the wealthiest tercile (25.1%, p<0.1). Differences in the coefficient of variation between the middle and wealthiest tercile are not statistically significant.

Similar to seed and fertiliser input prices also the by variety separated (LVN10, NK, CP, and other varieties/mixes) maize output prices are not consistently different between wealth terciles (Table 2-11). LVN10 output prices are significantly lower in the poorest compared to the middle (and wealthiest) terciles by 6.5% [p<0.1] (8.5%, p<0.05) in 2007, 9.0% [p<0.01] (13.8%, p<0.05) in 2008, and not significantly different in any other year. CP output prices are lower in the middle compared to the wealthiest tercile (8.7%, p<0.05) in 2008, higher in the poorest compared to the middle (17.9%, p<0.05) and wealthiest terciles (14.2%, p<0.1) in 2009, and otherwise not significantly different from zero. Other/mixed varieties prices are lower in the poorest compared to the middle tercile (15.8%, p<0.05) in 2007, lower in the poorest compared to the wealthiest tercile (8.6%, p<0.01) in 2008, and otherwise not significantly different from zero. NK output prices in any of the years are not statistically significantly different from zero between any of the wealth terciles.

Distance measures are arbitrarily correlated with maize output prices (Pearson correlation coefficient for all years). Distance to paved road (in walking minutes) is negatively correlated with LVN10 (-0.19, p<0.01) and other/mixed variety (-0.14, p<0.01) output prices, distance to district capital (Yen Chau) (km) is also negatively correlated with LVN10 (-0.28, p<0.01) and other/mixed variety (-0.17, p<0.01) output prices, and distance to closest market is negatively correlated with LVN10 output prices (-0.12, p<0.05) but positively correlated with NK varieties (0.12, p<0.05) and other/mixed varieties (0.14, p<0.05) output prices. However, as mentioned before market distance is also negatively related to paved road distance (-0.15, p<0.01). Any other correlations of distance measures with maize output prices are not significantly different from zero.

Effective maize output prices received, i.e. based on the variety mix chosen by households, are at the beginning of the period lower in the poorest tercile and evened out by 2010 when households of all wealth terciles grow the same variety mix. In comparison to the poor, realized maize output prices are by 6.4% [p<0.05] and 6.5% [p<0.05] higher in the middle and wealthiest terciles in 2007, by 4.4% [ns] and 8.0% [p<0.01] higher in the middle and wealthiest terciles in 2008, by 6.5% [p<0.05] and 3.8% [ns] lower in the middle and wealthiest terciles in

[31] The coefficient of variation measures the dispersion around the mean. In percentage, it is calculated as the standard deviation divided by the mean multiplied by 100.

2009, and not significantly different by wealth terciles in 2010. Differences between the middle and wealthiest terciles are never significantly different from zero.

Over time, maize output prices are volatile but with increasing tendency in all wealth terciles. Compared to 2007, effective maize prices decrease in the poorest, middle, wealthiest terciles by 5.4% [$p<0.05$], 7.1% [$p<0.01$], 4.1% [$p<0.1$] in 2008, increase by 22.5% [$p<0.01$], 7.7% [$p<0.01$], 10.7% [$p<0.01$] in 2009, and increase by 70.8% [$p<0.01$], 52.2% [$p<0.01$], 56.9% [$p<0.01$] in 2010 (differences between any other yearly comparisons [$p<0.01$] in all wealth terciles). In terms of differences in volatility between wealth terciles the coefficient of variation for effective maize output prices received is the highest in the poorest tercile reaching 47.1% compared to 38.4% [$p<0.05$] in the middle and 36.2% [$p<0.01$] in the wealthiest terciles (differences between the middle and wealthiest terciles are not significantly different from zero).

Net maize income is lower in the poorest compared to the middle and wealthiest terciles in all years but 2010 and highly volatile over the years in all wealth terciles, the most in the poorest tercile.

In the years 2007 to 2010, net maize income per hectare deflated by regional CPI to 2007 reaches in the poorest tercile 14.6 (1937), 10.6 (1414), 12.5 (1655), 15.9 (2114) million VND (USD PPP 2011), in the middle tercile 19.4 (2579), 13.9 (1850), 14.2 (1887), 17.4 (2308) million VND (USD PPP 2011), and in the wealthiest tercile 20.4 (2713), 15.2 (2015), 16.4 (2183), 18.2 (2419) million VND (USD PPP 2011), respectively.[32] Net maize incomes in the poorest compared to the middle (wealthiest) tercile are thereby lower by 33.2% [$p<0.01$] (40.1%, $p<0.01$) in 2007, 30.8% [$p<0.01$] (42.4%, $p<0.01$) in 2008, 14.0% [ns] (30.9%, $p<0.01$) in 2009, and 9.2% [ns] (14.4%, ns) in 2010. Differences in net maize income between the middle and wealthiest terciles are not significantly different from zero in all years.

Fluctuations in net maize incomes across years are significantly different in the poorest, middle, wealthiest terciles for 2007/2008, i.e. -27.0% [$p<0.01$], -28.3% [$p<0.01$], -25.7% [$p<0.01$], for 2007/2009, i.e. -14.5% [$p<0.05$], -26.9% [$p<0.01$], -19.5% [$p<0.01$], and for 2009/2010 not significantly different (yearly comparisons for 2008/2010 [$p<0.01$, all wealth terciles] and for 2009/2010 poorest [$p<0.01$], middle [$p<0.05$], wealthiest [ns], any other yearly comparisons are not significantly different from zero). Volatility measured as the coefficient of variation of net maize income is the highest in the poorest (44.7%) compared to the middle (37.9%, $p<0.05$) and wealthiest (35.7%, $p<0.01$) terciles. Differences between the middle and wealthiest terciles are not significantly different from zero.

[32] The conversion rate 1 USD = 7528.385 VND in purchasing power parity (PPP) for private consumption in 2011 (The World Bank, 2020).

2.4. Discussion of results and research and policy conclusions

Supporting farmers to intensify their farming systems remains a major goal of development economics. It is also one of the main policy goals of the Vietnamese government regarding the improvement of living conditions in the Northern Uplands of Vietnam (Nguyen, 2017). Given the general low asset levels in the Northern Uplands, explicit knowledge on how wealth affects technology adoption and intensification strategies of households in the Northern Uplands is however limited. Household wealth though may be critical for the ability to intensify agricultural production systems, such as maize cash crop production (Zimmerman and Carter, 2003). To close this research gap, this chapter of the doctoral thesis analyses how technology choices and intensification strategies between households of different wealth differ. For this reason, we first group households into wealth terciles based on an asset-based wealth indicator derived with PCA method (Henry et al., 2003; Zeller et al., 2006). In a second step, we analyse how input choice, intensification levels, and the results of intensification, in the form of yield and income, in maize production differ between households of different wealth. We run the analysis over the period from 2007 to 2010 to investigate how much household decisions and external incentives (i.e. prices) and in consequence production outcomes change over time.

From the results of this chapter's analysis, we conclude that even in mountainous and remote areas like Northern Vietnam, farming systems can be highly specialized and commercialized despite high altitudes, steep slopes, often poor soils, limited rural services, poor infrastructure, and the high levels of ecological risks farmers face. In our research area, agricultural production is characterized by very high upland shares and the dominance of maize production both regarding agricultural area and household cash income. The poorest households are however on average slightly more specialized and economically dependent on upland agriculture (80-82%), maize cultivation (76-84%), and maize share in cash income (73-74%) than the middle and wealthiest households (71-77%; 69-77%; 58-64%) (see also Keil et al., 2013; Ufer, 2010). Commercialization of maize harvest is equally intensive (92-97%) in all wealth terciles with small variations between years. Hence, differences in household wealth seem to have only a small impact on the tendency to specialize in maize production with a small positive skew towards the poorer end of the wealth distribution. These findings are in line with other findings from our research area that also find that the poorer households are stronger specialized in maize, while the middle and wealthiest households have relatively higher shares of income from rice, vegetables, fruit trees, and livestock (Keil et al., 2013).

Technology adoption of modern hybrid seed and mineral fertilisers is high in all wealth terciles, and households switch easily into new varieties. We find very high and dynamic adoption frequencies both for modern local and foreign maize hybrid varieties (MVs) as well as for mineral fertilisers, such as NPK and urea. Differences in adoption frequencies of MVs and mineral fertilisers between wealth terciles are minor. In 2007 (by 2010), 91% (98%) of the poor, 99% (99%) of the middle, and 100% (98%) of the wealthiest households use local (i.e.

LVN10) or foreign MVs (i.e. NK, CP, others) seeds.[33] High adoption rates of 90% MVs seeds for maize in the Northern Uplands have also been reported in other studies (Maredia et al., 2017).[34] Differences in variety mix (i.e. LVN10, NKs, CPs, others/mixes) between wealth terciles are small at the beginning of the period and none existent in the end. Instead, households switch variety types very quickly, from using predominantly the local hybrid LVN10 (49%), smaller shares of NK (17%), and other MVs/MV mixes (31%) in 2007 to using predominantly foreign hybrid NK varieties (49%), smaller shares of LVN10 (13%), and other MVs/MVs mixes (36%) in 2010. Comparison by wealth terciles shows that the wealthiest and middle terciles switch faster from LVN10 to NK varieties compared to the poor, perhaps assuming a pioneering role (Foster and Rosenzweig, 1995).

In terms of fertiliser adoption frequency, we also find high adoption rates in all wealth terciles. While at the beginning of the period the poorest adopt mineral fertilisers, such as NPK, urea, potassium or phosphorous, still somewhat less (i.e. 87% of the poorest compared to 100% in the middle and wealthiest terciles), at the end of the period the adoption rates between wealth terciles are the same (i.e. 100%). Moreover, use shares of different mineral fertiliser types are equal between households of different wealth terciles for NPK (70-77%) and urea (23-29%) and mostly equal for potassium and phosphorous (between 1-2%). Instead and similar to seed variety choice, fertiliser use shares change slightly in the direction of less NPK and more urea use in all wealth terciles, at similar potassium and phosphorous shares. Hence, regarding fertiliser input choice, like with seed input choice, we find hardly any remaining differences between wealth terciles at the end of the observational period.

From these results, we conclude that inputs must have become physical and financially widely available to households independent of wealth tercile. Reasons may be the relatively good infrastructure and market development after Doi Moi, the efforts of government extension services to promote input-intensive modern farming practices, the increasing engagement of private input suppliers and traders in maize production in the Northern Uplands, the wide availability of informal input credit, as well as the high profitability of maize that makes using inputs worthwhile (Kyeyune and Turner, 2016; Lançon et al., 2014; Luckmann et al., 2015; Minot et al., 2006; Saint-Macary, 2014; Thanh et al., 2004; Wezel et al., 2002a). The observation that the poor seem to take after the input decisions of the middle and wealthiest terciles over time shows that either hidden differences in the supply side, such as physical availability, transaction costs, or access to credit and extension, have diminished over time, and/or that production habits and knowledge may circulate between households of different

[33] Local non-hybrid variety seed share is based on the share of households that use local non-hybrid variety solely or in mixes.

[34] Maredia et al. (2017) find an adoption share (based on area) of modern improved maize varieties (MVs) of 90% compared to 10% local maize varieties for the Northern Uplands in the years 2014 to 2016. In detailed they find a share of single improved varieties of NK (14% NK4300, 9% NK7328, 7% NK66, 3% NK67), DK (9% DK9901, 7% DK9955), LVN10 (9% LVN10, 5% LVN99), CP (9% CP888, 5% CP501), 8% B9698, 5% Other MVs, as well as a share of local varieties of 10%.

wealth terciles reducing unfamiliarity and risk associated with new varieties through learning from earlier adopters (Foster and Rosenzweig, 1995). However, other studies from Northern Vietnam conducted in remoter places than our research area still report that maize input availability can be limited and timely not optimal (Kyeyune and Turner, 2016).

Regarding intensification decisions for seed and fertiliser input quantity, we find the same seed quantities but large differences in fertiliser quantity applied in the poorest compared to the wealthier terciles. Seed input quantity (21-24 kg/ha) is alike in all wealth terciles, whereby small differences in seed quantity at the aggregated household level over the period may have originated from switching varieties. Fertiliser input quantity, on the other side, is substantially lower and below recommendation levels in the poorest compared to the middle and wealthiest terciles. While the poorest tercile could improve their fertiliser use by 43% over the period, it still only reaches 59% (2007), 70% (2008), 70% (2009), and 78% (2010) of the recommended fertiliser levels of 1040 to 1220 kg/ha for the Northern Uplands (Staal et al., 2014: 80). The wealthier terciles, on the other hand, reach recommended fertiliser application levels of on average 95-108% (middle) and 94-104% (wealthiest) over the 2007 to 2010 period, with little variation in average fertiliser quantity applied over time. Hence, the poorest tercile still seems to be constrained to fully intensify their maize production, be it because of risk aversion, financial constraints, or some other factors, despite the ability to adopt modern technologies.

The data further suggest that in all wealth terciles a substantial share of households under- as well as overuses fertilisers. Not considering differences in variety choice or soil properties, and based on fertiliser application rates of more than 25% below or above the average recommendation (Staal et al., 2014), the poorest households underuse fertiliser significantly more often (51-69%) than households from the middle (27-50%) and wealthiest terciles (33-39%), while the share of households that overuse fertilisers is similar between wealth terciles in most years, reaching 7-16% in the poorest, 20-24% in the middle, and 17-29% in the wealthiest terciles between 2007 and 2010, respectively. Overuse of fertilisers has been reported for rice and coffee crops in Vietnam (Nguyen, 2017). It may originate from the appreciation of high yields (Nguyen, 2017), a lack of technical as well as financial knowledge of maize production (To-The and Nguyen-Anh, 2021), or uncertainty of the true nutrient content of fertilisers (Deng, 2012; Liverpool-Tasie et al., 2010; Nkana, 2016; Phien, 2013; Zahur, 2010). Moreover, we also find that for the poorest tercile an increase of fertiliser use of 27-28% (excluding 2010 the drought year) does result in a much lower increase in maize yields of up to 9% only. Reasons may be a lack of good soil fertility, knowledge (To-The and Nguyen-Anh, 2021), or of less likeliness in our research area, a lack of timely availability of inputs (Kyeyune and Turner, 2016).[35] In consequence, research and extension should not only

[35] Kyeyune & Turner (2016) report lack of timely availability of seed inputs as major obstacle to intensification for communes more remote than the ones researched here. We did not hear such reports for our research area.

pay attention to factors that determine farmers' intensification decisions but investigate into improved knowledge, the better adaptation of fertiliser recommendations, and the efficient use of inputs for households of all wealth terciles.

Monetary incentives between wealth tercile are hardly any different when seed input, fertiliser input, and maize output prices are considered separated by variety, fertiliser type, and payment arrangement (directly purchased, on-loan). We find however large and consistent differences in the propensity of the poorer households to buy seed and fertiliser on-loan compared to the wealthier terciles. While the overall share of households that purchased inputs on-loan is high in all wealth terciles, the poorer households significantly more often buy seed (64-74%) and fertiliser (76-88%) on-loan than the middle (seed: 37-45%; fertiliser: 52-62%) and wealthiest (seed: 23-43%; fertiliser: 38-56%) households. Additionally, the wealthiest tercile could reduce their dependency on-loan-based input purchases for seed (from 43% to 23%) and fertiliser (from 56% to 37%) over time, the poorest could reduce their dependency on-loan-based input purchases for fertilisers (from 89% to 77%) but not for seed, while the share of households that buy seed and fertiliser inputs on-loan in the middle tercile remained stable. These results are confirmed by other research reporting that households with more savings depend less on credit in Vietnam (Luan and Bauer, 2016).

Households that (have to) purchase seed and fertiliser input on-loan have to pay on average 21% and 17% higher prices, respectively, compared to households that purchase directly. This, in turn, may put poorer households that depend on loans for inputs still in a less favourable economic condition. So finds Saint-Macary (2014) in a study for our research area that the poorer households have lower total credit limit than the non-poor, take out overall smaller loans, and spend a lower share of their total loan outtake on agriculture and a higher share on food, social events, and other emergencies. Hence, the poorest households may face financial obstacles independent of the fact that they purchase a higher share of seed and fertiliser inputs on-loan. Moreover, the lower overall credit limit as found by Saint-Macary (2014) may also impact the investment behaviour of the poor through their ability to deal with risks (Dercon, 2002; Dercon and Christiaensen, 2011; Zeller et al., 1997).

In addition, we also find evidence on distance effects on prices, even though dissimilar in strength and direction for seed input, fertiliser input, and maize output prices. Distance measures (distance to paved road, closest market, and district capital) are barely related to direct and on-loan seed input prices, clearly related to direct and on-loan fertiliser input prices, particularly for distance to paved road, and arbitrarily related to maize output prices for different varieties. Given the multi-relational nature of the price-distance relationships, we suppose that these may result from differences in marketing arrangements. Since seed input is needed in smaller quantities (on average 22 kg/ha) and therefore more easily transported from a favourite seller by motorbike by farmers themselves, distance-related price impacts may just not be adequately reflected in seed input prices. This may also explain why road distance is positively related to fertiliser prices since fertilisers are needed in larger quantities (on average 1002 kg/ha) so that farmers may be more dependent on closer sellers, sellers that transport fertiliser to them, or agricultural marketing boards, such as the farmer union.[36] For maize output prices, other studies for the Northern Uplands report (Lançon et al., 2014; Luckmann et al., 2015) that maize output is often transported by farmers themselves, by the service of collectors or others, or directly traded with nearby local traders and whole sellers before being transported further. Such differences in marketing arrangements may explain the arbitrary relationships between distance measures and the reported variety-based maize output prices. Hence, comparing directly input and output prices by wealth tercile may somewhat disguise distance-related differences in input and output costs that could be found in more detailed marketing chain studies for the Northern Uplands (Lançon et al., 2014).[37] It also shows that farmers may be very active to find the best input and output arrangements so that distance-price relationships are reflected muted without adequately addressing all related transaction costs.

The relatively higher input prices caused by the higher loan dependency translate however not always directly into higher input cost for the poorest since the poorest households use a less expensive variety mix until 2009 (i.e. a higher share of the less expensive LVN10) and lower but increasing amounts of fertilisers (i.e. lower by 70-72% in 2007 to 24-29% in 2010). Total seed input cost in the poorest compared to the middle and wealthiest terciles is therefore similar until 2009 and 15-16% higher in 2010 (when all wealth terciles use the same variety mix). Total fertiliser input cost in the poorest compared to the middle and wealthiest terciles is lower by 63-64% (2007), 33-24% (2008), 41% (2009), and similar in all wealth terciles (i.e. 12-20% lower) in 2010. Total input cost in the poorest compared to the middle and wealthiest terciles is lower by 50% (2007), 26% (2008), 28-30% (2009), and not significantly different between wealth terciles in 2010. At the same time, from 2007 to 2010, seed and fertiliser input prices increase tremendously in all wealth terciles by on average 44% and 32% (78% and 35%) excluding (including) changes in input use patterns. Given the largest increases in input use and taken the effects of the changes in input intensity and input prices together, the poorest accomplish the highest increase in total input cost, reaching 105% in the poorest, 51% in the middle, and 43% in the wealthiest tercile from 2007 to 2010, respectively. Therefore, the poorest reach the same level of total input cost as the wealthier terciles at still lower fertiliser input levels of 24-29% by 2010 despite increasing input prices, while the middle and wealthiest households apply higher fertiliser amounts compared to 2007 in 2008 (9%) and 2009 (10-12%) before returning to 2007 fertiliser application levels in 2010. The tremendous increase in input prices further shows that the Northern Uplands most likely are well responsive to price volatility, such as general global trends of rising fuel and input costs that

[36] While farmers in the research area have the opportunity to transport their fertiliser inputs themselves by motorbike, given the quantity of fertilisers needed, they still might be more dependent on closer sellers or agricultural marketing boards to access fertilisers compared to seed input that can be more easily transported from longer distances, i.e. the district capital, whether households transport fertilisers themselves or not.

[37] Lançon et al. (2014) that measure marketing cost directly from one marketing chain partner to the next and by means of transport find distance-related differences for maize output prices in the Northern Uplands.

have been felt in many Asian countries, including Vietnam during the period (Dawe, 2008; Luckmann et al., 2015).

At the output level, the lower input levels, the relatively higher input cost, and the similar output prices lead to lower yields and lower maize gross margins in the poorest compared to the middle and wealthiest terciles. Maize yields in the poorest tercile are lower by 28-33% (2007), 24-28% (2008), 25-35% (2009), and insignificantly different in 2010 compared to the middle and wealthiest terciles with maize yields of 7.5-8.2 t/ha between 2007 and 2009 and 6.5 t/ha in the drought year 2010. Maize gross margins in the poorest tercile are lower by 33-40% (2007), 31-42% (2008), 13-31% (2009), and insignificantly different in 2010 compared to the middle and wealthiest terciles with average gross margins of 13.9-20.4 million VND/ha (1850-2713 USD 2011 PPP/ha) from 2007 to 2009 and 17.4-18.2 million VND/ha (2308-2419 USD 2011 PPP/ha) in the drought year 2010, respectively. All wealth terciles are further affected by substantial maize output price, maize yield, and maize gross margin variability, the poorest more than the middle and wealthiest terciles. Compared to 2007, maize output prices are lower by 4-7% in 2008, higher by 7-23% in 2009, and higher by 52-71% in 2010. Compared to 2007, maize yields are higher by 5-9% in 2008, higher by 0-4% in 2009, and lower by 2-17% in 2010. Net maize gross margins are lower by 26-28% in 2008, lower by 14-27% in 2009, and not significantly different in 2010 compared to the 2007 level. The poorest tercile faces however overall the higher volatility, with the coefficient of variation for maize yields, maize output prices, and the maize gross margin reaching 30%, 29%, and 45% compared to 25%, 24-25%, and 36-38% in the middle and wealthiest terciles. Hence, the relatively higher input prices, the lower fertiliser levels used, and the lower yields achieved in the poorest tercile transferred directly into a sizable net maize income gap in the poorest compared to the middle and wealthiest terciles. While the strong volatility in maize input and output prices can be interpreted as a sign of good integration of input and output markets with urban centres in Northern Vietnam and possibly the world market (Dawe, 2008; Luckmann et al., 2015), it also shows how susceptible households are to external price signals. In consequence, maize growing households have also to be able to deal with considerable production risks as well as decreasing profitability when increasing input prices cannot be matched by high enough compensation from rising output prices. This is further confirmed by other research that shows a large susceptibility of households in the Northern Uplands to decreasing maize output prices and its negative potential impact on the poor and the poverty reduction potential (Ngoc and Yokoyama, 2019; Thanh and Neefjes, 2005). Particularly then, when the strong specialization into maize may not just be seen as a sign of the good market integration and profitability of maize (Lançon et al., 2014; Wezel et al., 2002a) but also for a lack of (promoted) alternative profitable cropping choices, a lack of non-farm employment opportunities (Ngoc and Yokoyama, 2019; The World Bank, 2012), and a lack of assets and credit to diversify into more asset-intensive, sustainable, long-term on-farm and non-farm diversification strategies (Sadoulet et al., 2002; Sikor and Vi, 2005).

In light of the here presented results, we therefore overall conclude that analysis based on average numbers can indeed hide important differences when it comes to technology adoption, intensification strategies, yields, and net maize incomes between farmers of different wealth levels. In consequence, it may be advisable to develop research designs and extension messages that include the respective wealth-related agronomic, financial, and risk-related aspects. This includes the recognition and understanding of factors that determine the differences between wealth terciles regarding intensification levels and outcomes, financial access and financial management, and agronomical and economically efficient use of resources. Hence, more emphasis is needed on finding more detailed solutions to wealth-dependent obstacles households face regarding increased agricultural intensification and productivity to better support poor and less poor farmers alike.

3. Impact of risk aversion on fertiliser use: Evidence from Vietnam[38]

3.1. Introduction

Identifying the factors determining the intensity of fertiliser use is a common research focus (Duflo et al., 2011; Lambrecht et al., 2014; Takeshima and Nkonya, 2014). It is an input that is underused in some countries and overused in others, which can lead to low production in the former and environmental problems in the latter, such as biodiversity losses, eutrophication, air pollution, and nitrate leaching which contaminates water resources (Ebenstein, 2010; Liu et al., 2013; Yadav et al., 1997). Due to the uncertainty involved in using this input, examining how risk aversion may affect fertiliser intensity deserves more attention. Uncertainty can arise when low quality fertiliser, which contains fewer nutrients than that labelled on the package, is sold at markets. This creates doubts among consumers about the true nutrient content of fertiliser. This issue is more prevalent in developing countries (Deng, 2012; Liverpool-Tasie et al., 2010; Nkana, 2016; Phien, 2013; Zahur, 2010) and is especially problematic for smallholder farmers who do not have the means to test the nutrient content of fertiliser. In regions where trust in fertiliser quality is less of a concern, uncertainty can also occur because farmers may have doubts about the effectiveness of fertiliser in general and about the actual amount needed for their crops. This latter type of uncertainty is not restricted to farmers in countries with fertiliser quality problems and could thus affect farmers throughout the world.

Risk aversion could also affect fertiliser use intensity due to uncertain condition posed by weather variability and soil quality (Babcock, 1992; Dercon and Christiaensen, 2011; Isik and Khanna, 2003). Studies that examine risk behaviour and input use show that risk averse farmers apply less fertiliser (Roosen and Hennessy, 2003), and wealthier farmers are less risk averse (Binswanger, 1981; Chavas and Holt, 1996). We run the analysis using household production and risk aversion data collected in Vietnam, a country that is severely affected by fertiliser quality problems. This study is important to understand why there are varying intensities in the application rate among farmers and how risk aversion influences fertiliser intensity, which helps in developing policies to change fertiliser use pattern.

The chapter proceeds as follows: Section 3.2. presents the household production model, Section 3.3. explains the empirical study conducted and provides more information on the

[38] This chapter is an adapted version of an '**Accepted Manuscript'** of an article published by Taylor & Francis Group in Oxford Development Studies on 9 March 2018, Khor, L.Y., S. Ufer, T. Nielsen, and M. Zeller (2018) 'Impact of Risk Aversion on Fertiliser Use: Evidence from Vietnam', *Oxford Development Studies* 46(4): 483–96, available online: https://doi.org/10.1080/13600818.2018.1445212. Printed with the permission from Taylor & Francis Group.

variables included, Section 3.4. shows the results of the analysis and discusses about their implication, and Section 3.5. concludes.

3.2. Conceptual framework

In a household production model, let $h(F,X)$ be the production function of fertiliser F and other input X, p be the output price, and q and r be the input prices. Profit is $\pi = ph(F,X) - qF - rX$. We add a term ε to capture the uncertainty pertaining to farmer's belief about the true content or effectiveness of fertiliser, where $0 \le \varepsilon \le 1$. The lower bound of $\varepsilon = 0$ represents the case in which the farmer thinks that the fertiliser is fake or that the use of fertiliser is completely ineffective. The value of ε is one if the farmer believes that the fertiliser content is as labelled on the package. The expected profit is thus $E(\pi) = pE[h(\varepsilon F,X)] - qF - rX$ with a variance of $\sigma^2(\pi) = p^2\sigma^2(h)$. We follow Robison and Barry (1987) in analysing risk behaviour using the expected value - variance method, which maximises the certainty equivalent expression: $\max \pi_{CE} = E(\pi) - \gamma(W)/2\ \sigma^2(\pi)$. In this case, $\gamma(W)$ represents the level of risk aversion and it has a positive value for a risk averse individual. Following Binswanger (1981) and Chavas and Holt (1996), risk attitude can vary according to wealth, W.

Farm households need to produce a minimum amount of output to satisfy household needs, either as food for own consumption or as a product to be sold for cash. This minimum required level depends on the existing wealth of the households. For example, a high-wealth household will be able to cover for any potential shortfall in crop output, even without additional farm income, because their stock of wealth acts as an emergency fund for them during bad times. Low-wealth farmers do not have the same contingency reserve and thus face a minimum production constraint of $pE[h(\varepsilon F,X)] - qF - rX + W_0 \ge \overline{W}$, with W_0 being household wealth and $\overline{W}$ being the minimum wealth needed to satisfy household needs. This minimum amount reflects not only the basic consumption for survival, but can also include other aspects, such as education or more nutritious food, depending on each individual household. The Lagrangian of this is $\mathcal{L} = pE[h(\varepsilon F,X)] - qF - rX - \gamma(W_0)/2\ p^2\sigma^2(h) + \lambda\{pE[h(\varepsilon F,X)] - qF - rX + W_0 - \overline{W}\}$, with λ being the Lagrange multiplier. Assume that F is the input with uncertainty, X is the input without uncertainty, and both inputs are needed to produce the output. The first order conditions are

$$pE(\varepsilon h_F) - q - \frac{\gamma}{2}p^2\frac{\partial\sigma^2}{\partial F} + \lambda[pE(\varepsilon h_F) - q] = 0, \tag{3.1}$$

$$pE(h_X) - r + \lambda[pE(h_X) - r] = 0, \tag{3.2}$$

$$pE(h) - qF - rX + W_0 - \overline{W} \ge 0, \quad \lambda \ge 0. \tag{3.3}$$

The arguments of the risk and production functions are suppressed to simplify the notation. One of the inequalities in condition (3.3) has to hold as an equation due to complementary slackness. For the low-wealth farmers, there is a binding minimum production constraint with $pE(h) - qF - rX + W_0 - \overline{W} = 0$. High-wealth farmers are not bound by this constraint and thus $\lambda = 0$ for them.

Substituting $\lambda = 0$ into conditions (3.1) and (3.2) and combining them, we derive through implicit function theorem the effect of a marginal change in risk aversion on fertiliser intensity for high-wealth farmers:

$$\frac{\partial F}{\partial \gamma} = \frac{p\frac{\partial \sigma^2}{\partial F}}{2E(\varepsilon^2 h_{FF}) - 2E(h_{XF}) - \gamma p\frac{\partial^2 \sigma^2}{\partial F^2}} \,. \tag{3.4}$$

The direction of the effect depends on whether fertiliser is a risk increasing or risk decreasing input, and on its rate of change. If we assume that fertiliser is risk increasing (Roosen and Hennessy, 2003), then the numerator of equation (3.4) is positive. Due to diminishing marginal returns, the denominator is negative if fertiliser risk changes at a non-decreasing rate. In this case, an increase in individual risk aversion would reduce fertiliser intensity. However, if fertiliser risk changes at a decreasing rate, the effect of individual risk aversion on fertiliser intensity becomes ambiguous.

In contrast to the high-wealth farmers, the minimum production constraint is binding for the low-wealth group. Combining the first order conditions and using the implicit function theorem, the marginal effect of risk aversion on fertiliser intensity for farmers in the low-wealth group is

$$\frac{\partial F}{\partial \gamma} = \frac{p\frac{\partial \sigma^2}{\partial F}}{2E(\varepsilon^2 h_{FF}) - 2\lambda E(\varepsilon^2 h_{FF}) - \gamma p\frac{\partial^2 \sigma^2}{\partial F^2} - E(h_F) + \frac{q}{p}} \,. \tag{3.5}$$

An increase in risk aversion also lowers fertiliser intensity among low-wealth farmers if fertiliser risk changes at a non-decreasing rate. The effect is ambiguous otherwise. Which of the two wealth groups is more likely to have a negative marginal effect depends mainly on the magnitude of the two terms, $E(\varepsilon^2 h_{FF})$ and $E(h_{XF})$. If the expected content and effectiveness of fertiliser or its diminishing marginal return is low, i.e., the magnitude of $E(\varepsilon^2 h_{FF})$ is small, then the high-wealth group is more likely to have a negative marginal effect of individual risk aversion on fertiliser intensity compared to the low-wealth group. A possible reason is that when the expected fertiliser content is low, poor farmers who are risk averse might use more input than the unconstrained optimal level in order to produce enough output for an adequate level of household consumption. In the case of diminishing marginal return of fertiliser, as the low-wealth farmers have very limited resources, risk averse low-wealth farmers may be more willing to increase fertiliser intensity only if the reduction in the rate of marginal return is small. These two factors lead to an increase in fertiliser intensity when risk aversion rises, which is opposite to the negative marginal effect that risk aversion has on the application intensity of a risk increasing input. Thus, the marginal effect on fertiliser intensity is more likely to be negative for high-wealth farmers when the magnitude of the expected fertiliser content and diminishing marginal return of fertiliser is low. If the values of these two factors are high, then it is the low-wealth group that is more likely to have a negative marginal effect.

3.3. Empirical study

3.3.1. Fertiliser use intensity

We choose to focus our study on maize farming since it is the main crop grown in the region and is the largest contributor to cash income. The dependent variable of the regression analysis is the weight per hectare of all fertilisers applied in maize cropping by each household in 2010. This is the preferred choice for capturing fertiliser use intensity because all maize farmers in the region apply fertiliser and fertiliser weight is the measure that the farmers can recall clearly. For comparison purposes, we also repeat the analysis with three other measures of fertiliser use intensity: urea use intensity, NPK fertiliser use intensity, and the use intensity of the main fertiliser nutrient, nitrogen. As most of the farmers do not know or cannot recall the nutrient composition of the NPK fertiliser that they use, the approximate nitrogen use intensity is calculated from the nitrogen content in urea and the most common grade of NPK fertiliser in northern Vietnam (Shaddick, 2007).

3.3.2. Risk preference

The explanatory variables consist of risk preference and other control variables that capture household and maize farming characteristics. Since our main interest is the impact of risk aversion on fertiliser intensity, we analyse the effects of risk aversion elicited from two different techniques: a self-assessment question and a lottery game. The self-assessment scale is based on the German Socio-Economic Panel Study conducted by the German Institute for Economic Research (DIW Berlin). In this method, subjects are asked to choose from 0 (= fully avoiding risks) to 10 (= fully prepared to take risks). Responses are then rescaled so that it is in the order of increasing risk aversion.

The other risk preference elicitation method is a lottery game, also called the multiple price list technique, based on Holt and Laury (2002). In the lottery game, there is a safer option and a riskier option. The safer option has two possible payouts at 33,000 Vietnamese Dong (VND) or 41,000 VND. The two possible payouts for the riskier option are 2,000 VND or 79,000 VND.[39] Subjects are asked to choose between the safer option and the riskier option. The probability of the lower payout is 0.9 with the probability of the higher payout being 0.1. This game is repeated ten times but after each round the probability of the lower payout decreases by 0.1 while the probability of the higher payout increases by 0.1. The expected value (not shown to subjects) of the safer option is greater than that of the riskier option in the beginning but it switches after four rounds of choices. Risk preference is based on the total number of safe options chosen from the ten rounds of game and range from 0 which represents an extreme preference for taking risk to 9 which represents extreme risk aversion.[40] Subjects who selected ten safer options are excluded from the analysis since this is not a rational selection and it is likely that these subjects did not understand the lottery game. Assuming constant relative risk aversion for payout Y, a farmer's risk preference can be calculated from the following utility function:

$$U(Y) = \frac{Y^{(1-r)}}{1-r}, \qquad r \neq 1. \tag{3.6}$$

The highest payout amount is equivalent to about four times the average daily per-capita expenditure in our sample, 19,854 Vietnamese Dong (VND) or USD 2.60 after adjusting for purchasing power parity (PPP), meaning that potential payouts can be considered substantial.[41] The descriptive results in Table 3-2 indicate that according to the self-assessment scale, farmers are on average slightly risk averse with a mean of 5.14, which is on the risk averse side of the scale. This finding is confirmed by risk preference elicited in the lottery game. In the lottery game, respondents chose on average 6.30 safer options, indicating that respondents are on average risk averse.

3.3.3. Wealth

In order to test whether the effect of risk attitude on fertiliser intensity differs between wealth groups, we include an interaction term between risk aversion and household wealth in our regression model. The wealth measure is based on data collected in 2007, to avoid the problem of reverse causality from fertiliser intensity to wealth. The variable is constructed using principal component analysis (PCA) and follows the methodology by Henry et al. (2003) and Zeller et al. (2006). We use this method because it produces a multi-dimensional index that captures the different aspects of wealth, such as living conditions and total current value

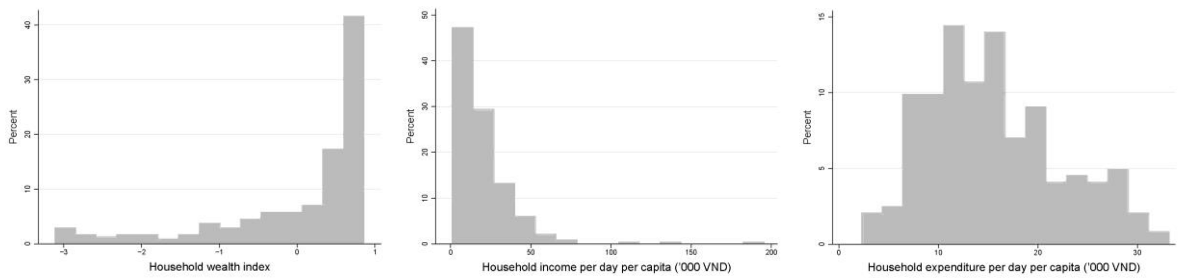
[39] The conversion rate in 2011 for the local currency, Vietnamese Dong (VND), after adjusting for purchasing power parity (PPP) is 7,625 VND / 1 USD (The World Bank, 2014).

[40] More specifically: 0 total safer option chosen represents extreme risk loving, 1 highly risk loving, 2 very risk loving, 3 risk loving, 4 approximately risk neutral, 5 slightly risk averse, 6 risk averse, 7 very risk averse, 8 highly risk averse, and 9 extremely risk averse.

[41] For more information on the lottery game method, we recommend Nielsen et al. (2013).

of assets. The choice of individual variables that reflect the relative poverty of the region allows us to focus more on the low-income households in the region by generating an index that has a wider spread at the lower end of the range, as opposed to the distribution of household income and household expenditure (Figure 3-1).

Figure 3-1: Frequency distribution of farmers' wealth based on three different measures of wealth



Wealth index Household income Household expenditure

Source: Own data

For comparison purposes, we also repeat the analysis using household income and household expenditure to represent wealth in order to examine any potential differences in the results. As the dataset does not contain information on total household income, we calculate it using the data from the two questions on maize income and its percentage in total income. Household expenditure includes all non-farm expenditure.

Table 3-1: Final list of indicators in the wealth index

Description	Mean	Loading
House exterior wall is made of bamboo (1 = yes, 0 = no)	0.11	−0.4896
House floor is earth with no covering (1 = yes, 0 = no)	0.15	−0.7169
Household has electricity (1 = yes, 0 = no)	0.91	0.7612
Household has own connection to electrical grid (1 = yes, 0 = no)	0.83	0.7820
Log(Total current value of cattle)	12.44	0.5681
Log(Total current value of television)	11.39	0.8505
Log(Total current value of motorcycle)	11.63	0.4126
Log(Total current value of living room furniture)	7.51	0.5841
Log(Total current value of cupboard)	10.22	0.7726

Source: Own data

We follow the procedures recommended by Henry et al. (2003) in filtering the indicators for the wealth index. The first step is to collect the potential variables that could be included in the different categories of wealth. We then run PCA on the variables and keep only the ones with a component loading higher than a pre-determined baseline, which based on the recommendation by Henry et al. is 0.30 in absolute value. Following this filtration, there are nine variables remaining. We list these variables in Table 3-1 together with their respective loading factors. We examine the validity of our final list of wealth indicators by checking whether it fulfils the following two criteria: its eigenvalue should be higher than one and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy has to be more than 0.60. Low KMO scores indicate that the variables have too little in common and the model is not appropriate. A score of 0.60 is considered mediocre, 0.70 is middling, 0.80 is good, and 0.90 is excellent (Kaiser, 1974). The eigenvalue for our index is 4.10 and it has a KMO measure of 0.84.

3.3.4. Control variables

Decision on rural livelihood strategies, such as agricultural intensification, may also be influenced by other factors (Scoones, 1998):

$$L = g(N, H, S, F), \tag{3.7}$$

with *N* being natural capital, *H* being human capital, *S* being social capital, and *F* being financial capital. We therefore control for these components, as well as maize production characteristics. Table 3-2 provides a summary of these variables. Size and quality of the cropping land are components of natural capital. Minten et al. (2013), Teshome et al. (2016), and Zerfu and Larson (2010) show that total farm area has a negative relationship with fertiliser use intensity after controlling for wealth. A possible reason is that farmers with a smaller area have to use their land more intensively to extract more output from the limited land that they have. We also include a variable that reflects soil quality since it can potentially alter the application of fertiliser (Lambrecht et al., 2014; Minten et al., 2013; Sinyolo et al., 2016). Households were asked in a previous round of survey to self-assess the quality of their maize plots on a 3-point-scale (1 = poor soil, 2 = average soil, 3 = good soil). As households typically produce maize on several plots, these scores are multiplied by the area share of each plot to obtain an indicator of soil quality. We hypothesise that soil quality has a negative relationship with the intensity of fertiliser use because farmers might apply more fertiliser if they think that the soil is poor and needs more nutrients.

We use the literacy dummy of the household head and the number of household adults above 15 year-old to capture the effect of human capital and labour availability (Ade Freeman and Omiti, 2003; Lambrecht et al., 2014). We include also the gender of household head in the regression (Marenya and Barrett, 2009a; Minten et al., 2013; Yagura, 2009). Households with literate household heads have better access to information, especially on new technology and inputs, thus could use a greater amount of fertiliser (Marenya and Barrett, 2009a; Zerfu and Larson, 2010). However, it is also possible that the effect is ambiguous, as the literate household heads may know more about the soil conservation techniques and thus apply less fertiliser. A higher labour availability is expected to increase the rate of fertiliser application.

Table 3-2: Description of variables

Description	Mean	Standard deviation
Total fertiliser use intensity for maize (kg/ha)	1102.25	858.10
Urea use intensity for maize (kg/ha)	320.14	314.13
NPK fertiliser use intensity for maize (kg/ha)	767.39	598.14
Nitrogen use intensity for maize (kg/ha)	185.63	167.12
Total farm area (ha)	1.72	0.96
Lagged self-assessed soil quality for maize cropping area[1)]	1.81	0.48
Household head can read and write (1 = yes, 0 = no)	0.83	0.37
Number of adults above 15 year-old per hectare of farm area	2.51	2.22
Percentage of lagged household income from off-farm sources	14.94	24.16
Gender of household head (1 = male, 0 = female)	0.91	0.28
Percentage of adult members with a leadership position in an organisation	8.16	18.18
Distance to Yen Chau city by motorcycle (minutes)	42.65	34.63
Household received any extension visits in past two years (1 = yes, 0 = no)	0.26	0.44
Self-assessed ease of access to agricultural extension[2)]	3.09	1.06
Average fertiliser price paid (‘000 VND/kg)	5.18	0.82
Percentage of lagged household income from maize production	72.58	26.88
Household uses local maize hybrid LVN only (1 = yes, 0 = no)	0.13	0.34
Household uses foreign maize hybrid CP only (1 = yes, 0 = no)	0.06	0.24
Household uses foreign maize hybrid NK only (1 = yes, 0 = no)	0.48	0.50
Household uses another or a mixture of hybrids (1 = yes, 0 = no)	0.33	0.47
Seed cost (‘000 VND/ha)	1546.83	663.40
Agrochemical cost[3)] (‘000 VND/ha)	61.84	200.08
Hired machinery cost (‘000 VND/ha)	266.12	527.79
Lagged maize yield (‘000 kg/ha)	7.38	4.79
Lagged maize output price (‘000 VND/kg)	3.62	0.69
Risk aversion based on the self-assessment scaled[4)]	5.14	2.36
Risk aversion based on the lottery game[5)]	6.30	1.97

Note: Summary statistics are calculated from the 243 observations in the main regression analysis.

1) Score from 1 to 3, with 1 = poor soil, 2 = average soil, and 3 = good soil.
2) Score from 1 to 5, with 1 = very bad and 5 = very good.
3) Includes pesticide, herbicide, and fungicide.
4) 0 represents extreme willingness to take risks and 10 represents extreme risk
5) Based on the total number of safer options chosen in the lottery game, ranging from 0 to 9.

Source: Own data

Lambrecht et al. (2014) show that off-farm income can usually be used as a proxy for financial capital because of its ability to facilitate the purchase of inputs by increasing cash availability. However, a study by Keil et al. (2013) conducted in Vietnam indicates that households with higher levels of off-farm income may be labour constrained and have to reduce investment in maize production. We construct a variable that reflects the share of off-farm income in total household cash income from a previous round of survey. Households with a large share of off-farm income may have less time to work on the farm and therefore may be less likely to crop as intensively compared to households that generate most of their cash income from agriculture (Yagura, 2009).

As a proxy for social capital, we include a leadership variable that measures the percentage of household adult members who are leaders in a political or social organisation. Such networks strengthen social ties, making it easier for the household to attain resources and information (Kormawa et al., 2003; Lambrecht et al., 2014; Sinyolo et al., 2016; Zerfu and Larson, 2010). Similar to the literacy rate, the direction of this effect is ambiguous. To capture the effect of access to markets and infrastructure we include a measurement of the distance in minutes to reach the capital of Yen Chau district, Yen Chau city, by motorcycle. We expect distance to have a negative relationship with fertiliser intensity due to the greater time and effort needed to go to the market for farmers in more remote areas and the higher costs involved in transporting fertiliser (Lambrecht et al., 2014; Marenya and Barrett, 2009a; Minten et al., 2013), which is usually carried out by farmers themselves on motorcycles in the study area. As low levels of fertiliser use could be caused by lower wealth or less information about best-practice application of fertiliser, we include in the regression the self-assessed ease of access to agricultural extension and a dummy variable on whether the household received any extension visits in the past two years as control variables (Kormawa et al., 2003; Marenya and Barrett, 2009a), in order to reduce the confounding effect between wealth and information. In addition to wealth, the ability to purchase fertiliser depends on the input price. Therefore, we include in the regression the average price paid for all fertilisers. Sheahan et al., (2016), Sinyolo et al. (2016), and Zerfu and Larson (2010) show that fertiliser price has a negative relationship with its use intensity.

We control for the impact of other maize cropping decisions by including the variables on the degree of specialisation in maize production (Ade Freeman and Omiti, 2003; Kormawa et al., 2003), the breed of maize planted (Marenya and Barrett, 2009a), the costs of other maize inputs (Kormawa et al., 2003; Marenya and Barrett, 2009a), and the yield and output price of maize from the past year (Sheahan et al., 2016; Zerfu and Larson, 2010). The degree of specialisation is represented by the percentage of household cash income from the previous year that comes from maize production. Ade Freeman and Omiti (2003) and Kormawa et al. (2003) find that farmers who focus more on cash crops or who have greater market orientations tend to apply more fertiliser. As maize is the main cash crop in the research area, a higher income share from maize production indicates that the household is more reliant on income from maize farming and is thus expected to have a higher fertiliser use intensity. To account for the type of maize breed, we use the most common local hybrid as the reference category and include the dummy variables of the other three types of maize breeds (foreign hybrid CP, foreign hybrid NK, and a mixture of hybrids). For the costs of other inputs used in maize production, we include seed cost, agrochemical cost, and hired machinery cost. We hypothesise a positive relationship between these variables and fertiliser intensity because higher costs of other inputs could indicate the farmers also use more fertiliser. Finally, higher yield and output price of maize from the past year are expected to increase the incentive of applying more fertiliser.

Given this study's focus on maize production, we exclude households that do not farm maize and those whose data on risk preference or household income are not available. This results in a sample of 243 households for the regression using wealth index, 235 households for the regression using household income, and 243 households for the regression using household expenditure. In order to check for potential biases caused by the exclusion of some households in the regression, we use two-sample t-test to compare the means of the included and excluded groups in all four measures of fertiliser intensity, three measures of wealth, and two measures of risk preference, respectively. This is conducted on the included and excluded groups in the regression with wealth index, on those in the regression with household income, and then on those in the regression with household expenditure. We compare also the means of all these variables between the maize and non-maize growing farmers. Test results show that the differences are not statistically significant at the 10% level in all cases.

3.4. Results and discussion

We examine the determinants of fertiliser use intensity for maize farmers, the output of which can be found in Table 3-3**.** We begin by running the analysis using OLS without the interaction term between wealth and risk preference,

$$F_i = \beta_0 + \boldsymbol{\beta_1 X_i} + \beta_2 w_i + \beta_3 r_i + \epsilon_i \,, \qquad (3.8)$$

with F_i being fertiliser use intensity, w_i being wealth, r_i being risk preference, and $\boldsymbol{X_i}$ being a list of control variables mentioned in Section 3.3. We then repeat the analysis with the interaction term included,

$$F_i = \beta_0 + \boldsymbol{\beta_1 X_i} + \beta_2 w_i + \beta_3 r_i + \beta_4 (w_i \times r_i) + \epsilon_i \,. \qquad (3.9)$$

In order to check for the robustness of the results and the potential variations due to the different ways of capturing fertiliser use intensity and wealth, we repeat the regression analysis with four different measures of fertiliser intensity (weight per hectare of all fertilisers, weight per hectare of urea, weight per hectare of NPK fertiliser, and weight per hectare of nitrogen in all fertilisers) and three separate indicators of wealth (household income, household expenditure, and a multi-dimensional wealth index constructed from living conditions and current value of assets).

Table 3-3: Selected regression outputs for fertiliser use intensity of all maize farmers

Variable	R1	R2	R3	R4
Total farm area	−116.081*** (33.311)	−110.848*** (38.528)	−109.699** (38.400)	−93.864** (42.781)
Household head literacy	333.592** (129.893)	344.722** (123.671)	291.875** (119.766)	179.799* (102.340)
Labour availability proxy	70.740*** (12.481)	75.560*** (12.228)	71.972*** (15.318)	68.207*** (18.222)
Lagged income % from off-farm	−4.139* (2.241)	−4.185* (2.150)	−4.266* (2.270)	−4.452* (2.376)
Gender of household head	5.537 (157.081)	−20.053 (157.618)	46.943 (147.811)	129.369 (172.838)
Distance to Yen Chau city	−2.902*** (0.833)	−2.453*** (0.793)	−2.865*** (0.801)	−2.667** (1.007)
Extension visits in past two years	−6.939 (115.037)	0.886 (119.226)	19.483 (103.749)	−16.161 (93.986)
Fertiliser price	−106.276** (45.592)	−111.996* (54.747)	−110.667** (49.098)	−107.633** (50.552)
Lagged income % from maize	3.527 (2.348)	3.012 (2.302)	3.138 (2.342)	2.190 (2.137)
Seed cost	0.211** (0.096)	0.214** (0.094)	0.250*** (0.080)	0.246*** (0.076)
Agrochemical cost	0.704 (0.609)	0.753 (0.604)	0.724 (0.629)	0.865 (0.624)
Hired machinery cost	0.186 (0.156)	0.196 (0.154)	0.181 (0.143)	0.179 (0.134)
Lagged maize yield	6.134 (9.769)	8.149 (8.349)	6.305 (9.908)	11.156 (9.353)
Lagged maize output price	177.916*** (43.150)	194.059*** (42.881)	155.550*** (49.791)	143.362** (56.215)
Lagged wealth index	−46.599 (79.720)	−335.850** (151.292)	−30.547 (77.430)	−602.360** (221.662)
Risk aversion (self-assessment)	−27.611 (21.270)	−31.232* (15.807)		
Risk aversion (lottery games)			−48.902 (43.821)	−60.595* (34.917)
Lagged wealth index × risk aversion		53.205*** (15.357)		93.734*** (26.373)
Observations	243	243	243	243
R-squared	0.320	0.341	0.326	0.361

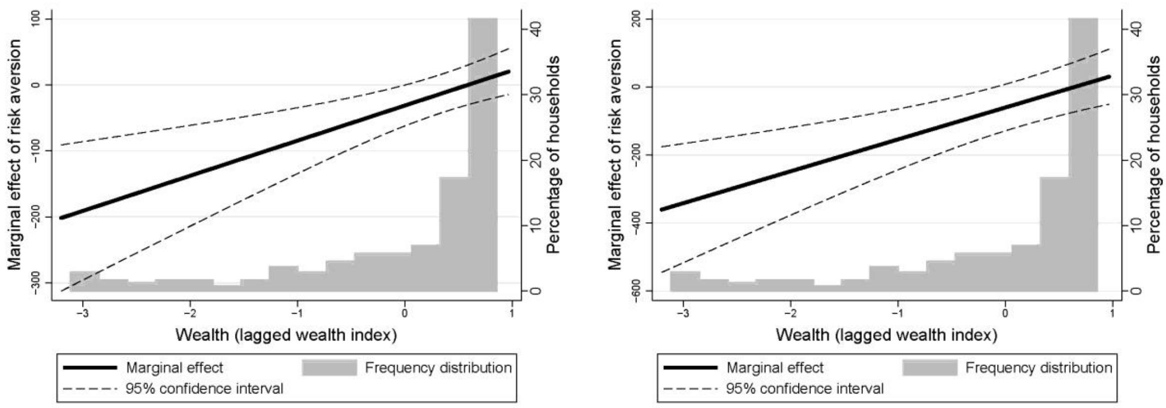
Note: Robust standard errors in parentheses, clustered at village level (*** p<0.01, ** p<0.05, * p<0.1)
Due to space limitations, we do not show the results of the maize breed, soil quality, extension access, and leadership position variables, which are all statistically insignificant. The results of these variables are available upon request.

Source: Own data

As the survey involves cluster sampling at the village level, we run the regressions with cluster robust standard errors. Columns R1 and R2 contain the results with the self-assessment measure of risk aversion and columns R3 and R4 contain the results with the lottery game measure. An interaction term of risk aversion and wealth is added into regressions R2 and R4. From the control variables, literacy of the household head and labour availability have a positive effect on fertiliser use intensity. On the other hand, the impact from total farm area, lagged off-farm income share, distance to Yen Chau city, and fertiliser price is negative. Lagged output price of maize from previous year has a positive effect on fertiliser use. Seed cost is significant and positive, but not the other input costs. This may result from a low use of hired machinery and agrochemical among farmers. Pests are not a major problem for maize since it is relatively new in the area, as the main crops used to be upland rice and cassava. In addition, rather than applying herbicide, weeding is usually done by hand. The infrequent use of these chemicals can be seen from their low costs per hectare in Table 3-2.

The main variable of interest for our analysis is risk aversion. We focus on how its impact on fertiliser use intensity varies across different wealth levels. As there is an interaction term of two continuous variables in regressions R2 and R4, we calculate the coefficient of risk aversion and its 95% confidence interval across the range of possible wealth index values in our survey sample. We show the results in Figure 3-2 which includes a histogram depicting the frequency distribution of the wealth index, as suggested by Berry et al. (2012) and Brambor et al. (2006).

Figure 3-2: Marginal effect of risk aversion across different wealth levels of farmers



Risk aversion based on self-assessment | Risk aversion based on lottery games

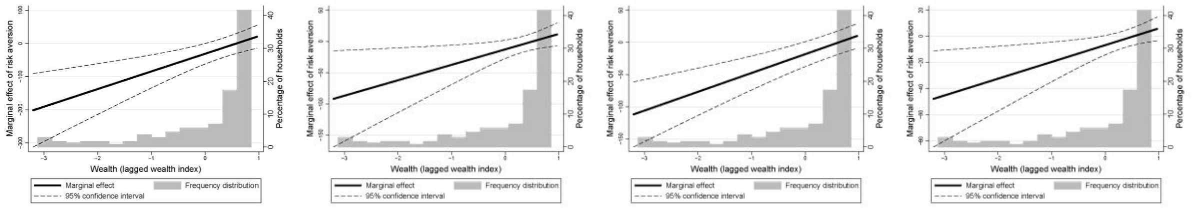
Source: Own data

We see that at the lower level of wealth, the marginal effect of risk aversion on fertiliser use intensity is significant and negative. The value becomes less negative and less significant as the wealth level rises, and becomes insignificant about two-thirds across the graph. The trend of the graph is the same for both measures of risk aversion, i.e. the self-assessment scale and the lottery games. The statistically significant part contains 32% of all households in the regression. For these farmers, an increase of one unit on the risk aversion scale reduces fertiliser application by 30 to 200 kg/ha based on the self-assessed risk aversion scale and by 70 to 350 kg/ha based on the lottery game risk aversion scale. This value depends on the wealth level of each household and the range of reduction between 30 and 350 kg/ha is equivalent to 3-32% of the mean fertiliser use intensity in the research area. The coefficients of both measures of risk aversion are insignificant for the farmers with higher wealth. As the number of clusters is small in estimating the robust standard errors, we follow the suggestion of Angrist and Pischke (2009, chap. 8) and rerun the analysis using the maximum of conventional and robust standard errors. The main results are consistent and show that the marginal effect of risk aversion on fertiliser use is negative and significant for the low-wealth farmers, containing 30% of all households in the regression. The coefficient at the higher wealth level remains insignificant.

3.4.1. Other measures of fertiliser use intensity

As there are alternative ways of measuring the intensity of fertiliser use, we rerun the regression using these different measures. Figure 3-3 shows the coefficient of risk aversion and its 95% confidence interval with the four different measures of fertiliser use intensity. Although there is a difference in the width of the 95% confidence interval, the trend of the coefficient remains the same, regardless of which measure of fertiliser intensity is used. Risk aversion has a negative and statistically significant effect on fertiliser use for the poorest one-third of farmers. The effect is insignificant for the farmers with higher wealth.

Figure 3-3: Marginal effect of risk aversion across different wealth levels of farmers using various measures of fertiliser use intensity



All fertiliser types | Urea | NPK fertiliser | Nitrogen content

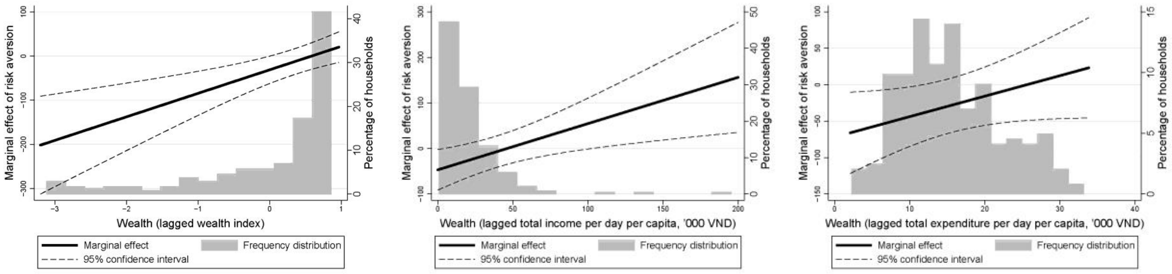
Source: Own data

3.4.2. Other measures of wealth

In the analysis above, we use a wealth index to represent household wealth because the index is multi-dimensional and captures the different aspects of wealth. We examine also the potential changes in outcome if we chose a different type of wealth indicator. In this case, we use the lagged household per-capita income and the lagged household per-capita expenditure, which are both more liquid indicators of wealth in comparison to the asset-based wealth index.

The results in Figure 3-4 show that even though there is a reduction in the statistically significant section when household income is used (9% of all households, compared to 32% and 35%, respectively, when wealth index and household expenditure are used), the trend remains consistent. Risk aversion has a negative effect on fertiliser use for farm households with the lowest wealth, regardless of whether household wealth is represented by wealth index, household income, or household expenditure. The effect becomes insignificant as wealth increases.

Figure 3-4: Marginal effect of risk aversion across different wealth levels of farmers using various measures of wealth



Wealth index | Household income | Household expenditure

Source: Own data

3.5. Conclusions

This chapter examines how risk aversion affects the intensity of fertiliser application and shows that the direction of the marginal effect depends on the wealth levels of farmers. It is negative and significant among farmers with the lowest wealth, and becomes insignificant at the higher end of the wealth indicator. Fertiliser quality is a growing concern in many countries. Risk aversion could lead to lower fertiliser use among low-wealth farmers. We compare the recommended level of nitrogen application in the research area (Tuan et al., 2014) with the approximate nitrogen use intensity of each household, calculated from the nitrogen content in urea and the most common grade of NPK fertiliser in northern Vietnam (Shaddick, 2007). Among the households who underuse nitrogen fertiliser, those from the poorest tercile apply significantly less of the input than the farmers with higher wealth. Uncertainty in fertiliser quality could worsen the situation because as shown in the analysis, risk aversion lowers fertiliser use among the low-wealth farmers. Thus, in addition to trying to understand more about the problem and how farmers deal with the situation, it is also important to have policies in place to prevent the doctoring of fertiliser content. Some possibilities include setting up a sector-wide monitoring body (Saenger et al., 2014) and giving special labels to products that meet a certain quality standard. Regular third-party testing of fertiliser sold at markets is also needed, including the testing of products that have already been awarded the special quality labels.

4. Determinants of agricultural productivity – decomposition analysis of maize income of smallholder farmers in Northern Vietnam

4.1. Introduction

The improvement of agricultural productivity remains an important concern to combat hunger, improve farm household incomes, and reduce poverty in developing countries. Reasons to favour agricultural growth as development strategy are in its potential to generate pro-poor growth (Ivanic and Martin, 2018). Improvements in agricultural productivity depend on the dissemination and adoption of new technologies, the level of input intensification, as well as on the efficiency with which households combine their assets and agricultural technologies to improve agricultural yields and incomes. However, assets, such as human, social, natural, physical, and financial capital, are not equally distributed among rural households, i.e. between countries, gender, different ethnic groups, and the poor and the non-poor (Nguyen et al., 2017; Van Tran et al., 2019; Tuyen, 2015; Zezza et al., 2011). This may lead to asset-based low productivity traps in agriculture, large income differences between farmer groups, and potentially to perpetual poverty traps (Cheng, 1996; Rosenzweig and Binswanger, 1993; Zimmerman and Carter, 2003). For Vietnam, a large body of research exists that extensively investigates (1) the extent and drivers of urban, rural, regional, and ethnic inequality patterns based on total income or consumption measurements (Baulch et al., 2007, 2012; Kang and Imai, 2012; Nguyen et al., 2017; Van De Walle and Gunewardena, 2001) as well as (2) the contribution of agricultural income inequality to overall income inequality (Benjamin et al., 2017; Nguyen et al., 2017; Tuyen, 2016). Research investigating factors that drive agricultural income gaps however gains less attention. While the share of agricultural income in total income (30.6% [20.2%]) and the contribution of agricultural income inequality to overall income inequality (12.4% [11.1%]) at the national level was small in 2002 [2014] (Benjamin et al., 2017)[42], in the Northern Uplands (2010) the shares of crop, livestock and aquaculture, and forestry incomes in total income were still as high as 47.1%, 12.2%, 11.3% and the contribution of crop, livestock and aquaculture, and forestry income inequality to

[42] In 2002 at the national level, the share in total income (the contribution of other income sources to overall inequality) by type of income was for wages 30.5% (33.7%), family business 23.0% (32.9%), and other income sources 15.5% (21.0%). In 2014 at the national level, the share in total income (contribution of other income sources to overall inequality) by type of income was for wages 40.9% (42.1%), family business 22.3% (30.8%), and other income sources 15.4% (17.3%) (Benjamin et al., 2017).

total inequality as high as 34.3%, 12.0%, 7.8%, respectively (Tuyen, 2016)[43]. The aforementioned findings (Benjamin et al., 2017; Tuyen, 2016) are however based on studies where the contribution of agricultural income to overall income inequality has to be interpreted as the combined effects of the share of households that participate in the respective working activity, the extent of hourly income differences, the total working time spend, and the effect of household size on per-capita income measures.[44] Hence, such studies can curtail the actual extent of agricultural productivity differences on a per-working-hour or per-hectare basis. Studies that additionally separate between the effect of differences in hourly wage and working time on differences in per-capita income find that differences in farm income per hour contribute 35.9% (46.5%) and differences in total working hours on the farm -33.8% (-35.4%) to total per-capita income differences between ethnic minorities in the Northern Uplands and a national comparison group (ethnic minority groups in other regions of Vietnam) (Nguyen et al., 2017). Hence, while the greater time worked on farm partly redeems the contribution of agriculture to total income differences between groups, actual net hourly labour gains in agriculture for ethnic minorities in the Northern Uplands are in comparison very low. The topic is further complicated by the fact that agricultural income differences may come from both low household asset levels as well as from low returns to employing these assets. We therefore contribute to the literature by investigating the sources of maize income gaps between poor and non-poor farmers in the Northern Uplands from an asset-based perspective, analysing how differences in the level of household endowments (i.e. assets) and differences in the returns to household endowments (i.e. assets) contribute to differences in maize incomes between poor and non-poor farmers based on a decomposition method initially proposed by Blinder (1973) and Oaxaca (1973). To the best of our knowledge, no such study has been undertaken for maize in Vietnam before.[45] The chapter proceeds as follows: Section 4.2. presents the conceptual framework and the decomposition method employed in the analysis, Section 4.3. describes the variables included in the empirical study, Section 4.4. presents and discusses the results of the analysis, and Section 4.5. draws the main research and policy implications.

[43] In 2010 in the Northern Uplands, the share in total income (the contribution of other income sources to overall inequality) by type of income was for wage 15.4% (27.6%), non-farm self-employment 3.1% (5.6%), and other income sources 11.0% (12.7%) (Tuyen, 2016).

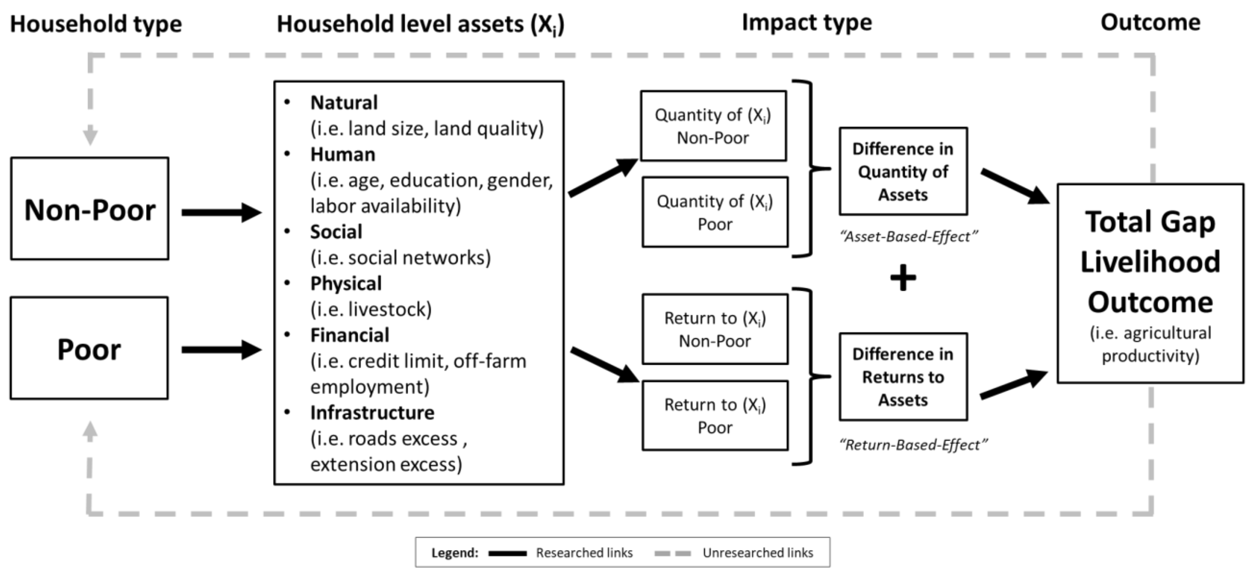
[44] The studies of Benjamin et al. (2017) and Tuyen (2016) are based on Shorrocks type decomposition methods (Shorrocks, 1982) that estimate the proportion of total inequality that can be attributed to different income sources. The method however compiles the effects of share of households that participate in a particular working activity, the hourly wage gap, and the number of working hours spend to generate a particular income source, as well as the effect of household size if per-capita income is used as basis.

[45] T. K. Van Tran et al. (2019) investigates the gender gap for rice incomes per hectare based on an Oaxaca-Blinder decomposition for Vietnam.

4.2. Conceptual and methodological framework

Assets, that is households endowments with human, social, natural, physical, financial, infrastructural, and political/institutional capital, are “the stock of wealth used to generate well-being” (Siegel and Alwang, 1999: 10). Assets thereby influence both households’ choices of livelihood strategies, such as agricultural intensification, as well as the livelihood outcomes generated through these strategies, such as increased income, increased well-being, or decreased poverty (Chambers and Conway, 1992; DFID, 1999; Scoones, 1998; Siegel and Alwang, 1999). However, livelihood outcomes may depend as much on the level of assets as well as on the return to assets. Of particular interest in this respect is which types of assets and which type of effect is responsible for outcome gaps between the poor and the non-poor (Figure 4-1). This chapter therefore analyses how differences in the level of assets and differences in the returns to assets contribute to differences in maize productivity between farmers of different wealth levels based on the decomposition method proposed by Oaxaca (1973) and Blinder (1973) (here forth OBD method).

Figure 4-1: Conceptual framework to analyse the impact of household assets



Source: Own depiction adapted based on Van Tran et al. (2019: 243)

While in the beginning the OBD method was mostly employed for the analysis of gender or race related wage differentials, the approach can also be utilized for similar analysis in other research fields. In development and agricultural economics, OBD methods have already been used to investigate total income and consumption gaps between different ethnic groups (Baulch et al., 2007, 2012; Nguyen et al., 2017; Van De Walle and Gunewardena, 2001), agricultural productivity gaps or differences in market participation associated with gender (Kilic et al., 2015; Marenya et al., 2017; Oseni et al., 2015; Van Tran et al., 2019), and differences in agricultural productivity between different crop varieties (Afidchao et al., 2014).

The advantage of this method lies in its ability to decompose a difference in an outcome variable between two groups (i.e. gender, ethnic groups, different varieties) into the part of the outcome gap that can be attributed to group differences in the level, i.e. quantity, of assets (first impact type, Figure 4-1, i.e. asset-based effect) and the part of the outcome gap that can be attributed to group differences in return to assets (second impact type, Figure 4-1, i.e. return-based effect). The first type of impact (asset-based effect) refers to the question of how much of the outcome gap between two groups could be closed if the lower performing group had the same level (i.e. quantity) of assets as the higher performing group. The second type of impact (return-based effect) refers to the question of how much of the outcome gap could be closed if the lower performing group had the same coefficient structure as the higher performing group, which is usually interpreted as the return to assets effect (Marenya et al., 2017: 4). The analysis also works if both effects are directed in the opposite direction, i.e. the asset level, i.e. asset-based effect, would increase (decrease) the outcome gap, but the coefficient structure, i.e. return-based effect, would work in the opposite direction decreasing (increasing) the outcome gap. With this, the analysis generates important additional information: to separate into what matters more for outcome levels – the differences in asset levels or in the level of returns to assets achieved by groups. It also offers a way to quantify the factors that are more important in an accounting sense to the outcome (Fortin et al., 2011: 3). This is particularly helpful for policy analysis since the important factors can be quantitatively identified and compared to the less important ones.

Following Baulch et al. (2012) and Jann (2008) the estimation strategy can be described as follows: Suppose there are two groups, in our case, a non-poor group (W) and the poor group (P) of households. Then the individual OLS equations describing the determination of log net maize income for each group separately can be written as follows:

$$lnNMI_W = X_W{}'\beta_W + u_W \tag{4.1}$$
$$lnNMI_P = X_P{}'\beta_P + u_P \tag{4.2}$$

where $lnNMI_j$ is the natural logarithm of household's net maize income per hectare, X_j is a $(k \times n)$ matrix of household characteristics, i.e. assets, β_j a $(k \times 1)$ vector of regression coefficients capturing the effects of households assets on log net maize income per hectare, and u_j a $(n \times 1)$ vector of random error terms for which the standard assumptions for estimation by ordinary least squares (OLS) apply, and the subscript $j = \{W; P\}$ describes the non-poor (W) and poor group (P), respectively.

Using the decomposition approach by Blinder (1973) and Oaxaca (1973) the estimated mean raw differential in log net maize income $(\hat{R})$ can be expressed as:

$$\hat{R} = \overline{lnNMI_W} - \overline{lnNMI_P} = \hat{Q} + \hat{U} = (\bar{X}_W - \bar{X}_P)'\hat{\beta}_W + \bar{X}_P'(\hat{\beta}_W - \hat{\beta}_P) \tag{4.3a}$$

where the overbar represents mean values, and the hat denotes OLS coefficient estimates.

The raw differential ($\hat{R}$) can now be split into two parts $\hat{R} = \hat{Q} + \hat{U}$, with the decomposition split further into the contributions of each single predictor and their individual returns, where $\bar{X}_{1j}$, $\bar{X}_{2j}$, … are the means of the single predictors and $\hat{\beta}_{1j}, \hat{\beta}_{2j}$, … are the associated coefficients. Then the first summand of the decomposition ($\hat{Q}$):

$$\hat{Q} = (\bar{X}_W - \bar{X}_P)'\hat{\beta}_W = (\bar{X}_{1W} - \bar{X}_{1P})'\hat{\beta}_{1W} + (\bar{X}_{2W} - \bar{X}_{2P})'\hat{\beta}_{2W} + \dots \qquad (4.3b)$$

reflects the part of the outcome differential that is explained by group differences in the predictor variables, the so-called "endowment" (Baulch et al., 2012; Blinder, 1973), or "quantity" (Jann, 2008), or in our case “asset-based” effect. The second summand of the decomposition ($\widehat{U}$):

$$\widehat{U} = \bar{X}_P'(\hat{\beta}_W - \hat{\beta}_P) = \bar{X}_{1P}'(\hat{\beta}_{1W} - \hat{\beta}_{1P}) + \bar{X}_{2P}'(\hat{\beta}_{2W} - \hat{\beta}_{2P}) + \dots \qquad (4.3c)$$

reflects the part explained by group differences in estimated returns to the predictor variables, i.e. the group's differential in coefficients, the so-called "treatment" (Baulch et al., 2012), or "discrimination" (Blinder, 1973; Jann, 2008), or in our case “return-based” effect, including the group's differences in intercepts ($\hat{\beta}_{oW} - \hat{\beta}_{oP}$) as well as any potential effects of differences in unobserved variables (Jann, 2008).

While equations (4.3a-c) describe the decomposition from the viewpoint of the first group, in this case the wealthy, meaning that all differences in the outcome gap would be attributed to the "positive" or "negative" effects of the first group over the second group, in this case the poor, the decomposition could alternatively be expressed by the viewpoint of the poorer group, then assuming that all differences in the outcome gap would originate from the "negative" or "positive" effects of the poorer group. However, computing such decompositions by this approach is suffering from the "index number problem" (Oaxaca, 1973; Oaxaca and Ransom, 1994 cited from Jann, 2008), meaning that the outcomes of these decompositions from the alternative viewpoint of either group in comparison would not be identical. Therefore, a third way that can be proposed is to use some non-discriminatory coefficients vector instead and to spilt the result into a part that can be attributed to the positive (negative) discrimination of the wealthier group and a part that can be attributed to the negative (positive) discrimination of the poorer group (Jann, 2008). In this respect, Neumark (1988) (cited from Jann, 2008) proposed to use a pooled regression as the reference basis for the decomposition, with $\widehat{\beta^*}$ as the non-discriminatory coefficient vector.

Using $\widehat{\beta^*}$ from the pooled regression as the non-discriminatory coefficient vector, then the decomposition would write as:

$$\hat{R} = \overline{lnNMI}_W - \overline{lnNMI_P} = (\bar{X}_W - \bar{X}_P)'\widehat{\beta^*} + \left[\bar{X}'_W(\hat{\beta}_W - \widehat{\beta^*}) - \bar{X}'_P(\hat{\beta}_P - \widehat{\beta^*})\right] \tag{4.4a}$$

with the asset-based effect for the detailed decomposition computed as:

$$\hat{Q} = (\bar{X}_W - \bar{X}_P)'\widehat{\beta^*} = (\bar{X}_{1W} - \bar{X}_{1P})'\widehat{\beta_1^*} + (\bar{X}_{2W} - \bar{X}_{2P})'\widehat{\beta_2^*} + \dots \tag{4.4b}$$

and the return-based effect for the detailed decomposition computed as:

$$\hat{U} = \left[\bar{X}'_W(\hat{\beta}_W - \widehat{\beta^*}) - \bar{X}'_P(\hat{\beta}_P - \widehat{\beta^*})\right] = \left[\bar{X}'_{1W}(\hat{\beta}_{1W} - \widehat{\beta_1^*}) - \bar{X}'_{1P}(\hat{\beta}_{1P} - \widehat{\beta_1^*})\right] + \left[\bar{X}'_{2W}(\hat{\beta}_{2W} - \widehat{\beta_2^*}) - \bar{X}'_{2P}(\hat{\beta}_{2P} - \widehat{\beta_2^*})\right] + \dots \tag{4.4c}$$

Empirically, we estimate our decomposition model (4.4a-4.4c) using the *oaxaca* command (Jann, 2008) in Stata 15. To adjust our decomposition model for sample selection bias that may result from differences in households cultivated maize share on log net maize income, we include into our regressions the residuals $\nu_i = y_i - x_i\hat{\beta}$ whenever $y_i > 0$ from a Tobit model on $y =$ household's cultivated maize share computed from all households with agricultural land (Wooldridge, 2012: 620).

4.3. Empirical study

4.3.1. Description of the regression sample

For the regression sample, we use the same households as in chapter 2.

4.3.2. Variables describing household wealth

To split our sample by wealth group, we use our wealth index generated by principal component analysis (PCA) for 2007 that we use in chapter 2 and chapter 3. We use the wealth index since it represents households' long-term economic condition rather than household income, which is for agricultural households inherently stochastic in nature (Baulch and Masset, 2003). Since differences in net maize income per hectare are not statistically significantly different between the middle and wealthiest terciles (chapter2), and the analysis on the effect of risk attitudes on fertiliser use run with the wealth index shows that risk attitudes affect the fertiliser use of the poorest one-third of households only (chapter 3), we run our regression and decomposition analysis by grouping the poorest tercile into the "poor" and the middle and wealthiest terciles into the "non-poor".

4.3.3. Description of variables included in the regression and decomposition analysis

Given its large share in household income (see chapter 2), our outcome variable of interest is net maize income per hectare. We express it in natural logarithm (log) to transform the dependent variable into an approximate normal distribution (Wooldridge, 2012).[46] Net maize income per hectare is computed as the value of total maize production minus the total value of variable input costs for seed and fertiliser, divided by total cultivated maize area. We do not include any pesticide (i.e. herbicide, insecticide) costs because they are generally not used in the research area. We deflate net maize income from different years as well as all other monetary control variables other than land value[47] by the regional consumer price index (CPI) as published by the General Statistics Office of Vietnam (GSO, 2011). We use regional instead of countrywide CPI to better adjust for regional differences in prices.

Based on the conceptual framework above, describing outcomes of households' livelihood decisions from a capital (asset) based perspective (Chambers and Conway, 1992; DFID, 1999; Scoones, 1998; Siegel and Alwang, 1999), we include the following explanatory variables into the regression and decomposition models.

For natural capital, we include land value adjusted farm area and a proxy for upland soil quality. For value adjusted farm area (thousand VND m²), we hypothesize a positive (Luan and Kingsbury, 2019; Yamano and Kijima, 2010) or negative relationship with net maize income per hectare (Asfaw et al., 2016; Gebremedhin et al., 2009; Minot et al., 2006; Smith, 2008). A positive relationship may exist when larger land size supports economies of scale or credit access through collateral, a negative relationship may exist when households with smaller landholdings farm their land more intensively than households with larger landholdings (inverse-farm-size-productivity-relationship), which is very often the case in developing countries (Carletto et al., 2013). To control for upland soil quality, we include the average land value of the households' cultivated upland area (VND per m²) as a proxy. We focus on the soil quality of the upland since maize is predominantly grown on upland fields (95.2% of all maize grown).[48] We hypothesize a positive relationship with net maize income per hectare because

---

[46] Using the natural logarithmic form of positive monetary economic variables, such as wages or income, is a popular method to transform highly skewed, non-normally distributed outcome variables into an approximate normal distribution. Models with dependent variables (y) transformed in this manner have the advantage that they allow for nonlinear relationships between the explained and explanatory variables, satisfy the classical linear model assumptions more closely than models using the level of y, mitigate possibly heteroskedasticity and skewedness, and lower the influence of outliers by reducing the range of the variable (Wooldridge, 2012: 191–4).

[47] The land value per plot, measured as rent paid for rented in plots and as rent that could be claimed for owned plots, was collected in 2007, and the average land value for subsequent years is then adjusted for the number of plots in use. Since land value generally rather increases in value with inflation than decreases, we do not deflate this variable.

[48] Average for the years 2007 (96.0%) and 2010 (94.8%) for which we have data.

better intrinsic soil fertility can increase the returns from fertiliser applications and increase crop income (Asfaw et al., 2016; Gebremedhin et al., 2009; Marenya and Barrett, 2009b; Yamano and Kijima, 2010).

For human capital, we include the education level of the household head, the age of the household head, the sex of the household head, the ethnicity of the household head, and the labour availability of the household. Education (number of years) is one of the most important key human capital variables since it can increase the returns to agricultural activities through better knowledge. We hypothesize a positive relationship with net maize income per hectare (Gebremedhin et al., 2009; Luan and Kingsbury, 2019; Minot et al., 2006; Van Tran et al., 2019). We also include the age of the household head (number of years). The effect of age might be ambiguous. Older farmers may profit from larger experience, but younger farmers may profit from more innovativeness. Hence, the impact of age may be positive or negatively associated with net maize income per hectare (Luan and Kingsbury, 2019; Minot et al., 2006; Van Tran et al., 2019). The sex of the household head (included as dummy variable, 1=male) may also have an impact on the outcome. While a gender effect not automatically can be anticipated, i.e. many studies find no impact of gender on agricultural productivity or crop income (Gebremedhin et al., 2009; Luan and Kingsbury, 2019; Smith, 2008; Yamano and Kijima, 2010), other studies find a positive impact for males over females (Asfaw et al., 2016; Minot et al., 2006; Van Tran et al., 2019). Since the research area is home to several ethnic groups, namely the ethnic minority groups Black Thai and Hmong and the ethnic Vietnamese majority group Kinh, we decide to control for the ethnicity of the household head (dummy variables each for Hmong and Kinh, the Black Thai represent the reference group).[49] Ethnicity of the household head may influence crop income through differences in agricultural traditions and practices, location-based variables, or some form of structural discriminatory effects (Kyeyune and Turner, 2016; Michaud et al., 2002; Tran, 2003; Van De Walle and Gunewardena, 2001). We do not have an explicit hypothesis about the direction of these effects. However, it is often mentioned that the Hmong tend to live in the highest altitudes, have high poverty rates, with a tendency to favour traditional live styles, that the Black Thai tend to live at lower altitudes, are often less poor, and are often stronger integrated, whereas the Kinh are often the wealthiest and best connected people group (Kyeyune and Turner, 2016; Michaud et al., 2002; Van De Walle and Gunewardena, 2001). For labour availability (measured as the number of household members above 15 years per hectare of farm area), we hypothesize a positive relationship with net maize income per hectare since higher labour availability per unit of land allows timely and more intensified cropping (Luan and Bauer, 2016; Minot et al., 2006).

For financial capital, we include the total credit limit and the share of cash non-farm income. Total credit limit (thousand VND, in logarithmic scale) is measured as all formal and informal

[49] The numbers represent the average ethnic composition for the years 2007 to 2010. Differences between years are minor and not statistically significant (see also Table 4-1, p.79).

credit the household can currently access plus current outstanding debt (Diagne et al., 2000). Overall credit access is supposed to have a positive impact on crop income by allowing larger input investments and by increasing the risk-bearing capacity of households (Zeller et al., 1997). Current evidence on the impact of rural credit market participation on agricultural production for Vietnam is rather mixed. While some studies find a positive impact of credit received on agricultural income for some farmer groups (i.e. less poor, ethnic minorities) (Luan and Bauer, 2016) or crops (i.e. bamboo) (Luan and Kingsbury, 2019), the same studies find a negative impact of credit received on agricultural income by other farmer groups (i.e. wealthiest, Kinh) (Luan and Bauer, 2016), most likely because of different fertilisation practices and a tendency of some farmers to overuse fertiliser in certain crops (Nguyen, 2017). Moreover, the studies mentioned above do not discern between credit access and participation in the credit market. While the first definition (credit access) includes also all households that could borrow but for any reason decide not to, the second definition (participation) only includes households that actually borrow. The distinction is important for two reasons. Firstly, households still can be credit constraint to various degrees even when they are actively borrowing because they may have received only a part of the credit they desired, while other households that borrow still have to various degrees credit limit left. Secondly, the mere access to credit can have a positive impact on households because credit does not only serve as current means to finance investments but also as future means to secure consumption in risky environments (Diagne et al., 2000; Zeller et al., 1997). Hence, open credit lines allow households to invest in more risky agricultural activities, whether they decide to borrow or not. However, given the current evidence on credit market participation in Vietnam and the option households have to overuse fertilisers in crops, we anyhow decide not to hypothesize the type of relationship of credit access with net maize income per hectare. For the share of cash non-farm income in total household cash income (percentage), we hypothesize a positive or negative relationship with net maize income per hectare depending on whether the non-farm cash income would be used to finance farm inputs and support farming (positive impact) (Stampini and Davis, 2009), or non-farm cash income would limit labour availability to households and lead to less intensified cropping (negative impact) (de Brauw, 2010; Keil et al., 2013).

For physical capital, we include the total value of cattle and buffalo owned by the household (thousand VND, measured in logarithmic scale). We hypothesize a positive relationship with net maize income per hectare since the ownership of cattle and buffalo supports timely field preparation and may also promote saving and risk management (Asfaw et al., 2016; Gebremedhin et al., 2009; Smith, 2008).

For infrastructure, we include the access to extension and the distance to paved road. For extension access (share of households in the village that consider their extension access to be good based on self-assessment)[50], we hypothesize a positive relationship with net maize income per hectare since extension increases the access to information, supports higher returns, and decreases the risk of using technologies (Gebremedhin et al., 2009; Van Tran et al., 2019). We use the share of households in the village with good extension access rather than individual extension access because maize is a long-established crop and households in a village may share extension information. We also hypothesize a positive relationship of paved road access (distance to paved road in walking minutes) with net maize income per hectare because road access is supposed to facilitate access to input and output markets and reduce time and cost for transport (Yamano and Kijima, 2010).

To adjust the regressions for selection bias that may result from differences in households cultivated maize share, we include the residuals from the respective Tobit regressions computed as: $\hat{v}_i = y_i - x_i\hat{\beta}$ whenever $y_i > 0$, with $y_i =$ household's cultivated maize share, $x_i =$ household characteristics, $\hat{\beta} =$ the estimated Tobit regression coefficients (Wooldridge, 2012: 620). To estimate the Tobit models, we use all households that cultivate agricultural land, whether they cultivate maize or not. For x_i in the selection model all independent variables of the OLS regression models are included plus the following variables to determine the selection: average land value of all household farmed area (VND per m^2, logarithmic scale), household share of upland area (percentage), average distance to upland plot (walking minutes, logarithmic scale), household share of paddy area (percentage), household area share of red book certificate (=land title) (percentage), elevation (m), share of dependents below 15 and above 64 years (percentage).

4.4. Results and discussion

4.4.1. Explanation and discussion of regression results

Table 4-1 summarizes the variables of asset endowments included in the regression and decomposition analysis. Variables included as logarithmic values in the regression and decomposition models are described as exponentiated values in the text and as logarithmic values in Table 4-1 and the respective footnotes. Mean comparison tests between the poor and non-poor are reported on a yearly basis from 2007-2010, pair-wise comparison tests for differences between years for the poor and non-poor groups are reported for 2007 compared to 2010 only.[51]

[50] Self-assessment of extension access is graded by households on a Likert-scale from 1 (very poor access) to 5 (very good access). In the analysis, households that graded their extension access with 3.0 or better are considered households with good extension access.

[51] Since most of the asset-based variables included in the regression and decomposition model are measured for the years 2007 and 2010 only and the 2007 (2010) values included in the 2008 (2009) regressions, we only show the results of the yearly-pairwise mean comparison tests for the years 2007 to 2010.

The results from Table 4-1 show that in most asset categories the poorer group is significantly lower endowed.

In terms of natural capital, the poor have significantly lower values of agricultural land area and cultivated upland value. Value corrected land area is on average about 44.7% lower in the poorest compared to the non-poor group, at 8.2, 8.3, 8.5, and 8.2 million VND times square meter in the poor compared to 12.0 (+46.6%, $p<0.01$), 11.8 (+42.4%, $p<0.01$), 12.3 (+44.0%, $p<0.01$), and 11.9 (+45.7%, $p<0.01$) million VND times square meter in the non-poor group in 2007 to 2010, respectively. In comparison to physical land area only, differences in value corrected land area are therefore much higher (see Table 2-3, chapter 2, p.25). Like physical land area, value corrected land area is quite stable over time, with no statistically significant differences between years in both the poor and non-poor groups. The value of upland area (exponentiated values), as a proxy for land quality, are on average about 8.4% lower in the poorest compared to the non-poor group. Upland land value is 345, 345, 361, and 346 VND per square meter in the poorest and 375 (+8.7%, $p<0.05$), 373 (+8.0%, $p<0.05$), 375 (+3.9%, ns), and 391 (+13.0%, $p<0.05$) VND per square meter in non-poor group in the years 2007 to 2010, respectively.[52] Differences between years are not significantly different from zero in the poor (-0.3%, ns) and significantly different in the non-poor group (+3.4%, $p<0.05$).

Regarding human capital, many of these variables are significantly lower in the poorest household group, too. From 2007 to 2010, like in the overall sample (see also Table 2-3, chapter 2, p. 25), the poor have a larger share of household heads that belong to the ethnic minority group Hmong, i.e. 49%, 48%, 44%, and 48% [$p<0.01$, for all years], compared to none in the non-poor group, respectively. The share of Kinh majority household heads is equal (i.e. not statistically significantly different) between the poor (on average 6.0%) and non-poor (on average 7.8%) in all years. In consequence, this also means that the share of Black Thai minority households is lower in the poor compared to the non-poor group. Ethnic composition is in the poor and non-poor groups stable over time (not statistically significantly different from zero in any of the years). The poorest have household heads of lower age. The average age of the household head in the poor group is 37.9, 38.5, 39.7, and 40.6 years and in the non-poor group 45.4 [$p<0.01$], 46.3 [$p<0.01$], 47.2 [$p<0.01$], and 48.5 years [$p<0.01$] from 2007 to 2010, respectively. Differences between 2007 and 2010 are statistically significantly different from zero in the poorest [$p<0.01$] and non-poor group [$p<0.01$]. However, since we have a panel sample tracking the same households, this result should be interpreted as the progression of age in the sample.

[52] The respective logarithmic values [statistics] for upland land value are 5.61, 5.61, 5.66, 5.62 for the poor, 5.76 [$p<0.1$], 5.76 [$p<0.1$], 5.77 [ns], 5.80 [$p<0.05$] for the non-poor for the years 2007 to 2010, respectively. Differences between 2007 and 2010 are statistically insignificantly different from zero in the poor and significantly different at the 5%-level of error probability in the non-poor group, see also Table 4-1.

Table 4-1: Descriptives of variables included in regression and decomposition models

Independent Variables	2007 Poor	2007 Non-poor	Sig	2008 Poor	2008 Non-poor	Sig	2009 Poor	2009 Non-poor	Sig	2010 Poor	2010 Non-poor	Sig
Farm area, value adjusted [million VND m²]	8.19 (7.45)	12.01 (9.21)	***	8.30 (7.59)	11.82 (8.86)	***	8.52 (7.56)	12.27 (9.71)	***	8.18 (7.33)	11.92 (9.86)	***
Log land value upland [VND/m2]	5.61 (0.67)	5.76 (0.57)	*	5.61 (0.66)	5.76 (0.56)	*	5.66 (0.68)	5.77 (0.56)		5.62 (0.66)	5.80[B] (0.57)	**
Age HH head [years]	37.89 (13.72)	45.43 (10.58)	***	38.47 (13.46)	46.33 (10.69)	***	39.73 (13.68)	47.20 (11.28)	***	40.56[A] (13.61)	48.47[A] (11.05)	***
Education HH head [years]	3.53 (3.67)	7.20 (3.70)	***	3.60 (3.62)	7.21 (3.68)	***	3.56 (3.50)	6.64 (3.66)	***	3.34 (3.39)	6.65[A] (3.67)	***
Sex HH head [1=male]	0.92 (0.27)	0.93 (0.25)		0.92 (0.27)	0.94 (0.24)		0.89 (0.32)	0.93 (0.26)		0.90 (0.31)	0.93 (0.26)	
Ethnic group = Hmong [1=Hmong]	0.49 (0.50)	0.00 (0.00)	***	0.48 (0.50)	0.00 (0.00)	***	0.44 (0.50)	0.00 (0.00)	***	0.48 (0.50)	0.00 (0.00)	***
Ethnic group = Kinh [1=Kinh]	0.06 (0.23)	0.08 (0.27)		0.06 (0.23)	0.08 (0.27)		0.06 (0.23)	0.07 (0.27)		0.06 (0.23)	0.08 (0.27)	
Labour availability [adults > 15yrs/ha]	2.13 (1.97)	2.59 (2.17)	***	2.11 (1.95)	2.60 (2.17)	***	2.35 (3.03)	2.46 (1.68)	***	2.23 (2.91)	2.81[B] (2.54)	***
Off-farm income [%]	13.01 (18.68)	13.83 (21.39)		13.82 (20.21)	14.35 (22.01)		16.84 (25.77)	16.02 (24.09)		13.34 (21.96)	17.74 (26.14)	
Log credit limit, deflated [000 VND]	9.67 (0.83)	10.64 (0.63)	***	9.46 (0.84)	10.45 (0.62)	***	10.31 (0.75)	11.13 (0.66)	***	10.22[A] (0.74)	11.07[A] (0.66)	***
Log value cattle/buffalo, deflated [000 VND]	4.86 (4.59)	8.76 (2.62)	***	4.75 (4.49)	8.61 (2.52)	***	6.07 (4.53)	8.94 (2.84)	***	6.31[A] (4.40)	8.76[A] (2.94)	***
HH with good extension access in village [%]	0.69 (0.23)	0.70 (0.18)		0.69 (0.22)	0.70 (0.18)		0.55 (0.18)	0.59 (0.20)		0.56[A] (0.18)	0.58[A] (0.20)	
Distance paved road [walking min]	26.02 (26.04)	12.68 (13.52)	***	25.78 (25.90)	12.57 (13.52)	***	23.47 (25.63)	12.69 (13.58)	***	25.63 (25.93)	12.73 (13.49)	***
Observations [N]	88	181		90	177		88	171		87	176	

Note: *** p<0.01, ** p<0.05, * p<0.1 indicate a significant difference at the respective level of error probability for group-wise comparisons, i.e. poor/non-poor by year

A p<0.01, B p<0.05, C p<0.1 indicate a significant difference at the respective level of error probability for year-wise comparisons, i.e. 2007/2010 by poor; 2007/2010 by non-poor

Source: Own data

Education levels of the household head are lower in the poorest group. They are slightly below the level of primary education of 3.5, 3.6, 3.6, and 3.3 years in the poorest group and about twice as high, i.e. 7.2 [p<0.01], 7.2 [p<0.01], 6.6 [p<0.01], and 6.7 [p<0.01] years, in the non-poor group in 2007 to 2010, respectively. In the non-poor group, the decrease in the education level of the household head between 2007 and 2010 is significantly different at the 1%-level of error probability. Differences in education level for the poor are not significantly different between 2007 and 2010. What may look surprising at first, can be a result of the higher likeliness of better educated households to migrate for work to bigger urban centres as some studies show for Vietnam (Phan, 2012). The poorest group also has lower amounts of household labour available. While the poorest group has, respectively, 2.1, 2.1, 2.4, and 2.2

number of adults (above fifteen years old) available per hectare agricultural land from 2007 to 2010, the non-poor can rely on 2.6 [p<0.01], 2.6 [p<0.01], 2.5 [p<0.01], and 2.8 [p<0.01] adults per hectare agricultural land from 2007 to 2010. Differences in labour availability between 2007 and 2010 are not statistically significantly different in the poorest group and statistically significant [p<0.05] in the non-poor group.[53] Human capital variables that are not statistically significantly different between the poor and non-poor as well as across years are the share of households with Kinh households heads and the share of households with male household heads (over the years, on average, 90.8% and 93.3% in the poor and the non-poor group, respectively).

Regarding financial capital, the poor have a lower amount of credit limit and a lower value of cattle and buffalo. Credit limit (exponentiated values) in the poorest group is about 20.6, 16.6, 38.0, and 35.0 million VND compared to 51.9 (+152%, p<0.01), 42.5 (+156%, p<0.01), 87.7 (+131%), and 81.4 (+133%, p<0.01) million VND in the non-poor group in 2007 to 2010, respectively. Differences between 2007 and 2010 are significantly different both in the poorest [p<0.01] and in the non-poor group [p<0.01], which means an increase in credit limit in the poorest by 69.7% and non-poor group by 56.9% between 2007 and 2010.[54] Value of cattle and buffalo (exponentiated values) is 5.8, 4.9, 9.3, and 9.0 million VND in the poorest group and 15.2 (+163.4%, p<0.01), 12.5 (+167.2%, p<0.01), 19.9 (+112.4%, p<0.01), and 17.7 (+96.0%, p<0.01) million VND in the non-poor group from 2007 to 2010.[55] From 2007 to 2010, increases in value of cattle and buffalo are statistically significantly different in the poorest (+56.9%) [p<0.01] and non-poor group (+16.7%) [p<0.01].[56] Share of off-farm income is not statistically significantly different between the poor (over the years, on average, 14.3%) and the non-poor (over the years, on average, 15.5%) in any of the years as well as not statistically significantly different between the years 2007 and 2010 in the poor and non-poor groups.

[53] While the increasing labour availability simultaneously to the decreasing education level of the household head in the non-poor group from 2007 to 2010 may seem a bit contradictory, cross-checking the data with the development of the household size (number household members) as well as the dependency ratio (dependents below 15 and above 64) shows that both the household size (from 4.7 to 4.5 [p<0.05]) and the dependency ratio (from 0.26% to 0.23% [p<0.05]) decrease from 2007 to 2010, respectively. Hence, while in the non-poor group household heads may migrate for income earning possibilities elsewhere, household labour availability does not decrease at the same time since the number of dependents in households decreases also.

[54] The respective logarithmic values [statistics] for credit limit are 9.67, 9.46, 10.31, 11.13 for the poor, 10.64 [p<0.01], 10.45 [p<0.01], 11.13 [p<0.01], 11.07 [p<0.01] for the non-poor for the years 2007 to 2010, respectively. Differences between 2007 and 2010 are significantly different in the poor [p<0.01] and the non-poor group [p<0.01], see also Table 4-1.

[55] Based on the average value of one adult male head of buffalo of around 15 million in 2007, this means that the poor own on average buffalo and cattle below one head, while the non-poor own on average buffalo and cattle above one head.

[56] The respective logarithmic values [statistics] for value of cattle and buffalo are 4.86, 4.75, 6.07, 6.31 for the poor, 8.76 [p<0.01], 8.61 [p<0.01], 8.94 [p<0.01], 8.76 [p<0.01] for the non-poor for the years 2007 to 2010, respectively. Differences between 2007 and 2010 are significantly different in the poor [p<0.01] and the non-poor group [p<0.01], see also Table 4-1.

Regarding infrastructure, distance to the closest paved road (in walking minutes) is significantly different. The poor need about twice as long to the paved road as the non-poor. From 2007 to 2010, the poor need on average 26.0, 25.8, 23.5, and 25.6 walking minutes to the paved road, in comparison, the non-poor need only 12.7 [$p<0.01$], 12.6 [$p<0.01$], 12.7 [$p<0.01$], and 12.7 [$p<0.01$] walking minutes, respectively. Differences between 2007 and 2010 are not statistically significantly different neither for the poor nor the non-poor. Not different between the poor and non-poor are the share of households with good extension access in the village (based on self-assessment scale) in any of the years. The share of households with good extension access in the poor and non-poor group however decreases from 69% and 70% in 2007 to 56% [$p<0.01$] and 58% [$p<0.01$] in 2010, respectively. Hence, extension activity either decreases or households become less satisfied with it.

Table 4-2 to Table 4-4 describe the results of the OLS regressions that are the basis of the decomposition analysis. The regression models highlight the factors that influence net maize income per hectare for the following household groups: for all households combined (Models 1.1 to 1.4, Table 4-2, p.86), the poor (Models 2.1 to 2.4, Table 4-3, p.87), and the non-poor (Models 3.1 to 3.4, Table 4-4, p.88) for the years 2007 to 2010.

Looking first at model fit, the R-squared values are the highest for the poor household models, where 58.3%, 52.8%, 45.4%, and 24.0% of the variance in the dependent variable can be explained by the regressions in 2007, 2008, 2009, and 2010, respectively. The R-squared for the overall models are also high, reaching 40.9%, 41.1%, 34.2%, and 12.5%, while the R-squared for the non-poor models are 24.8%, 23.9%, 30.8%, and 9.9% for the years 2007, 2008, 2009, and 2010, respectively. Hence, assets explain outcomes of net maize income per hectare the best in the poor household regressions, while somewhat less for the overall and the non-poor household regressions. Looking at the overall significance of the model, the F-test is for all models above 0.0000, except for the non-poor model in 2008 ($F=0.0002$) and the overall ($F=0.0002$), poor (0.0003), and non-poor (0.0261) models in 2010. For 2010, the reason for the lower overall significance in all models can most likely be explained by the overall drought impact in the research area in 2010. Drought can increase the variability of yields, reduce the impact of fertiliser on yield outcomes (which application rates depend on assets itself, see chapter 3), and hence dampen the overall impact of assets on the outcome. This is also confirmed by fewer explanatory variables being significantly different from zero in the 2010 regression models compared to previous years.

Looking at the impact of the independent variables included in the models, value adjusted farm area yields a negative association with net maize income per hectare. The coefficients are significantly different from zero in the OLS regressions of all households from 2007 to 2010, whereby one unit increase in value adjusted farm area decreases net maize income per hectare by 0.64% [$p<0.05$] in 2007, 1.1% [$p<0.01$] in 2008, 0.77% [$p<0.1$] in 2009, and 0.64% [$p<0.1$] in 2010, respectively (M1.1 to M1.4). In the poor household regressions coefficients are significantly different from zero from 2008 to 2010, with one unit increase in value adjusted farm area decreasing net maize income per hectare by 0.94% [$p<0.1$] in 2008, 3.42%

[p<0.01] in 2009, and 1.85% [p<0.01] in 2010, respectively (M2.2 to M2.4). In the non-poor household regressions coefficients are significantly different from zero in the year 2008, where one unit increase in value adjusted farm area decreases net maize income per hectare by 0.76% [p<0.05] in 2008 (M3.2). Hence, smaller farms have higher land productivity per hectare than larger ones in terms of maize income across all households, the poor, and for the non-poor to a lesser extent. These results are consistent with the often observed "inverse-farm-size-productivity-relationship" that finds that households with smaller landholdings use their land more intensively (Asfaw et al., 2016; Carletto et al., 2013; Gebremedhin et al., 2009; Minot et al., 2006; Smith, 2008). We find that the effect is larger and more consistent for the poor than the non-poor household group. One explanation may be that the poor struggle more than the non-poor with resource scarcities because of lower initial resource levels and with the task to increase seed and fertiliser application once land size increases (Rusinamhodzi et al., 2016).

Upland land value as a proxy for upland soil quality shows a very consistent positive relationship with net maize income per hectare considering all households 2007 to 2010 ([p<0.01], [p<0.01], [p<0.01], and [p<0.05]; M1.1 to M1.4, respectively). Regression coefficients are significantly different from zero for the poor from 2007 to 2010 ([p<0.01], [p<0.1], [p<0.05], and [p<0.05]; M2.1 to M2.4, respectively) and for the non-poor from 2007 and 2009 ([p<0.05], [p<0.05], and [p<0.01]; M3.1 to M3.3, respectively). Except for a slightly weaker effect in the drought year 2010, the effect is strong and consistent, which is in line with literature that shows positive impacts of soil fertility on yields, returns to fertiliser, and the value of crop income (Asfaw et al., 2016; Gebremedhin et al., 2009; Marenya and Barrett, 2009b; Yamano and Kijima, 2010).

Ethnicity in the regressions of all households is positively correlated when the ethnicity of the household head is Kinh (ethnic Vietnamese) compared to Black Thai (minority) in the years 2007 [p<0.01; M1.1] and 2008 [p<0.01; M1.2]. The coefficient is negatively correlated when the ethnicity of the household head is Hmong (minority) compared to Black Thai (minority) in 2007 [p<0.05; M1.1]. In the non-poor regressions, having a household head that is Kinh compared to a household head that is Black Thai is also positively correlated in the years 2007 [p<0.01; M3.1] and 2008 [p<0.05; M3.2], whereas the variable for Hmong households drops out since none of the Hmong households is non-poor. Any of the ethnicity variables in the poor regressions are statistically insignificant in any of the years (M2.1 to M2.4). Hence, ethnicity of the household head has some impact on net maize income per hectare at the beginning of the period considering the regressions of all households and the non-poor but no impact on the poor. This compares with general findings from Vietnam that ethnicity can have an impact on livelihood outcomes, which may result from differences in (agro)-cultural practices, location, preferences, asset levels, returns to assets, or other ethnic-specific variables (Baulch et al., 2012; Kang and Imai, 2012; Michaud et al., 2002; Nguyen et al., 2017; Tran, 2003; Van De Walle and Gunewardena, 2001). At the same time, relationships between ethnicity and livelihood outcomes can be quite complex. While the overall ethnic minority disadvantage on income and consumption expenditures is well documented (Baulch et al., 2012; Kang and Imai, 2012; Nguyen et al., 2017; Van De Walle and Gunewardena, 2001), evidence on the relationship between ethnicity and crop income is more mixed. So finds a study on coffee production in Vietnam's Central Highlands, higher per hectare coffee income of the Kinh majority group compared to the local Ede minority group (Doutriaux et al., 2008). Another study on cinnamon farming in a province in the Northern Uplands finds lower per hectare cinnamon income of the Kinh majority group compared to the local ethnic minorities (Luan and Kingsbury, 2019). Yet, other studies find no impact of ethnicity on crop incomes at all, like Minot et al. (2006) on overall per hectare crop income in the Northern Uplands and Luan and Kingsbury (2019) on per hectare bamboo income. Hence, our results confirm, while the ethnicity of the household head can have an impact on income from cropping, these differences may depend on the type of crop and may change over time.

The coefficient of labour availability is positively related to net maize income per hectare and significantly different from zero in the regressions for all households from 2007 to 2009 ([$p<0.1$], [$p<0.05$], and [$p<0.01$]; M1.1-M1.3, respectively), the poor from 2007 to 2009 ([$p<0.1$], [$p<0.05$], and [$p<0.1$]; M2.1-M2.3, respectively), the non-poor in 2008 and 2009 ([$p<0.05$] and [$p<0.01$]; M3.2 and M3.3, respectively), and statistically insignificant in any of the regressions in 2010. These results are in line with our expectations given the apparent absence of mechanization and the large amount of manual labour involved in upland cropping systems. The results further are in line with other findings that show a positive impact of household size or labour availability on crop incomes in Northern Vietnam (Luan and Kingsbury, 2019; Minot et al., 2006).

Any of the other human capital variables are most of the time not significantly different from zero, like the sex of the household head (only significantly different from zero in the non-poor regression [$p<0.1$] in 2007), the education of the household head (never significantly different from zero in any of the regressions), the age of the household head (only significantly different from zero considering all households (negative coefficient [$p<0.05$]) and the non-poor (negative coefficient [$p<0.01$] in 2007), and the share of households that have good extension access in the village (never statistical significantly different from zero). The low significance of these variables may be explained by the fact that maize is a very dominant and well-established crop in the research area. In the Northern Uplands, hybrid maize production already got introduced since the 1990s and is, together with modern inputs such as chemical fertilisers, heavily promoted by the government (Thanh et al., 2004; Thanh and Neefjes, 2005). In consequence, age, education, sex, and extension related differences may be less important for maize-specific production knowledge, production habits, and income since households may learn and share information over longer times (Foster and Rosenzweig, 1995).

The share of off-farm income is negatively associated with net maize income per hectare for all households in 2007 and 2008 ([$p<0.01$], [$p<0.05$]; M1.1-M1.2, respectively), the poor 2007 to 2009 ([$p<0.05$], [$p<0.05$], [$p<0.1$]; M2.1-M2.3, respectively), and the non-poor in 2007 ([$p<0.05$]; M1.3). Hence, having a larger share of off-farm income contributes to lower net maize income per hectare, especially in the poorest household group that already has lower amounts of family labour available, probably because it reduces the labour available to farming. Hence, off-farm labour most likely acts as a substitute for agricultural family labour rather than as an additional financial source to buy more inputs and intensify maize farming. This is in line with studies from Vietnam that show that off-farm income can reduce the share of land allocated to maize (Keil et al., 2013) and that migration can reduce the amount of fertiliser and labour supplied to agriculture (de Brauw, 2010).

Households' credit limit (measured in logarithmic scale) has a significant positive association with net maize income per hectare. In respect to all households, a one-percentage (20-percentage) increase in credit limit increases net maize income per hectare by 0.07% (1.28%) [p<0.05] in 2007, 0.17% (3.06%) [p<0.01] in 2008, and 0.14% (2.60%) [p<0.05] in 2010, respectively (M1.1-M1.3). In respect to the poor, a one-percentage (20-percentage) increase in credit limit increases net maize income per hectare by 0.26% (4.81%) [p<0.01] in 2008 (M2.2). In the non-poor regressions, a one-percentage (20-percentage) increase in credit limit increases net maize income per hectare by 0.09% (1.71%) [p<0.1] in 2008 and 0.13% (2.38%) [p<0.1] in 2009 (M3.2 and M3.3, respectively).[57] In 2010, credit limit is insignificant in all regressions for all household groups. These results are supported by other research in Vietnam that finds a positive impact of credit market participation on farm income of ethnic minority households in Vietnam (Luan and Bauer, 2016) and on bamboo income in the Northern Uplands (Luan and Kingsbury, 2019). The stronger impact and significance in the years 2008 and 2009 may have resulted from households' larger financial needs because of increasing input prices (chapter 2). The insignificant value during 2010 most likely results from the drought impact that reduces the efficiency of the fertiliser input used. It also shows that maize in the Northern Uplands seems to be a crop that is not yet on average over-fertilised in economic terms like some studies show for rice and coffee for some areas in Vietnam (Nguyen, 2017), or studies that show a significant negative impact of credit market participation on crop income for the wealthiest (quintile) households (Luan and Bauer, 2016).

The value of cattle and buffalos owned by households (measured in logarithmic scale) has a positive impact on net maize income per hectare in the regressions of all households in 2008 [p<0.1] and 2010 [p<0.05], the poor in 2007 [p<0.05], 2008 [p<0.1], and 2010 [p<0.05], and the non-poor in 2010 [p<0.1]. The positive impact of cattle on crop income can originate from animal traction supporting timely agricultural management, such as field preparation (Smith, 2008). The more consistent effect for the poor may come from their stronger constraints in this respect since their cattle ownings are much lower than for the non-poor. When transformed into an on-head basis, on average, the poor own below one head of cattle or buffalo, while the non-poor own above one head of cattle or buffalo in all years (see Table 4-1, p.79). The positive impact may also result from positively influencing households' risk

[57] For logarithmic values: if the independent variable x increases by 1% then the dependent variable y increases by β – per cent, if the independent variable x increases by α-per cent then the dependent variable y increases by $\left(1.\alpha^{\beta} - 1\right) * 100$ per cent.

behaviour. Khor et al. (2018) (chapter 3) find that risk aversion in the poorest one-third of households has a negative impact on fertiliser quantity used, whereas fertiliser application rates of the wealthier farmers do not change with their risk aversion level. Hence, a reliable asset base may be especially important for the poorer farmers as a basis for agricultural investment.

Distance to paved road has some but not a very consistent significant impact on net maize income per hectare, with a positive effect in 2008 [$p<0.01$] considering all households, a negative impact in 2009 [$p<0.01$] considering the poor, and never significant effect for the non-poor. As mentioned in chapter 2, the low impact of paved road distance may either be a result of relatively well integrated maize markets in Northern Vietnam or origin from relatively competitive but complicated marketing chains engaging several collectors and traders and the possibility for farmers to actively engage. So finds research on maize marketing in the Northern Uplands that marketing chains often involve several actors for transport and purchase as well as the possibility for farmers to self-transport, which may somewhat disguise the actual transaction cost involved (Lançon et al., 2014; Luckmann et al., 2015).

We also include the residual from the Tobit regressions on household maize share in the OLS regressions to account for any bias that may originate from households growing different shares of their land with maize (Wooldridge, 2012). The Tobit-residuals are negatively associated with net maize income per hectare considering all households in 2008 [$p<0.01$], 2009 [$p<0.01$], and 2010 [$p<0.05$], the poor in 2008 [$p<0.1$], 2009 [$p<0.01$], and 2010 [$p<0.1$], and the non-poor in 2007 [$p<0.05$], 2008 [$p<0.01$], and 2009 [$p<0.01$]. Hence, growing a larger share of maize does not automatically support maize productivity. Such results can originate when in mono-cropping systems, labour peaks for field preparation, fertiliser application, and harvesting are more pronounced than in more diversified cropping systems, when with a larger maize share also less suitable land for maize is cultivated, or when fertiliser is spread over a larger maize area rather than stronger concentrated (Rusinamhodzi et al., 2016).

We also include a dummy variable for the poor in the combined regressions (Jann, 2008). This dummy variable is not significantly different from zero in any of the years. Hence, the assets we include in the regressions seem to control well for asset-related differences between the poor and the non-poor.

Table 4-2: Regression results – All households

VARIABLES	(M1.1) 2007 All HH	(M1.2) 2008 All HH	(M1.3) 2009 All HH	(M1.4) 2010 All HH
Farm area, value adjusted [million VND m²]	-0.0064** (0.0028)	-0.0111*** (0.0023)	-0.0077* (0.0043)	-0.0064* (0.0032)
Log land value upland [VND/m2]	0.1842*** (0.0402)	0.1925*** (0.0490)	0.2175*** (0.0525)	0.0967** (0.0340)
Age HH head [years]	-0.0055** (0.0020)	0.0000 (0.0023)	-0.0026 (0.0034)	-0.0001 (0.0029)
Education HH head [years]	0.0050 (0.0065)	0.0032 (0.0066)	0.0133 (0.0109)	0.0108 (0.0101)
Sex HH head [1=male]	-0.0238 (0.0667)	-0.1023 (0.1028)	-0.0529 (0.1263)	-0.0871 (0.1787)
Ethnic group HH head [1=Hmong]	-0.2369** (0.0907)	-0.1296 (0.0811)	-0.0854 (0.1489)	0.0752 (0.1742)
Ethnic group HH head [1=Kinh]	0.3474*** (0.0920)	0.2987*** (0.0838)	0.0029 (0.1123)	0.0312 (0.0849)
Labour availability [adults > 15yrs/ha]	0.0285* (0.0143)	0.0405** (0.0163)	0.0650*** (0.0190)	0.0074 (0.0165)
Off-farm income [%]	-0.0040*** (0.0013)	-0.0032** (0.0014)	-0.0021 (0.0015)	-0.0010 (0.0015)
Log credit limit, deflated [000VND]	0.0701** (0.0329)	0.1655*** (0.0417)	0.1410** (0.0611)	0.0341 (0.0421)
Log value cattle/buffalo, deflated [000VND]	0.0067 (0.0082)	0.0176* (0.0097)	0.0070 (0.0131)	0.0339** (0.0132)
HH with good extension access in village [%]	-0.0243 (0.1006)	-0.0286 (0.0860)	-0.0354 (0.2798)	0.1854 (0.2395)
Paved road distance [walking min]	-0.0022 (0.0019)	0.0033*** (0.0009)	-0.0035 (0.0025)	-0.0005 (0.0027)
HH is poor [1=poor]	-0.1012 (0.0878)	-0.0945 (0.0859)	-0.0790 (0.1207)	-0.0476 (0.0772)
Tobit-residual HH maize share	-0.0025 (0.0015)	-0.0041*** (0.0011)	-0.0132*** (0.0013)	-0.0058** (0.0024)
Constant	8.2574*** (0.4000)	6.6245*** (0.5160)	6.7331*** (0.6968)	8.4323*** (0.5451)
Observations	269	267	259	263
R-squared	0.4089	0.4111	0.3424	0.1250
Adj_R2	0.3739	0.3759	0.3019	0.0719
Prob > F	0.0000	0.0000	0.0000	0.0002

Robust standard errors in parentheses, clustered at village level (*** p<0.01, ** p<0.05, * p<0.1)

Source: Own data

Table 4-3: Regression results – Poor households

VARIABLES	(M2.1) 2007 Poor	(M2.2) 2008 Poor	(M2.3) 2009 Poor	(M2.4) 2010 Poor
Farm area, value adjusted [million VND m²]	-0.0088 (0.0060)	-0.0094* (0.0054)	-0.0342*** (0.0095)	-0.0185* (0.0098)
Log land value upland [VND/m^2]	0.2103*** (0.0456)	0.1707* (0.0987)	0.2759** (0.1105)	0.1513** (0.0689)
Age HH head [years]	-0.0042 (0.0035)	0.0008 (0.0050)	0.0064 (0.0053)	0.0028 (0.0045)
Education HH head [years]	0.0145 (0.0135)	0.0155 (0.0141)	0.0199 (0.0239)	-0.0198 (0.0238)
Sex HH head [1=male]	-0.2132 (0.1693)	-0.2918 (0.1796)	0.0126 (0.2565)	-0.1760 (0.2193)
Ethnic group HH head [1=Hmong]	-0.1297 (0.1588)	0.0580 (0.1181)	0.0203 (0.1915)	0.0838 (0.2160)
Ethnic group HH head [1=Kinh]	0.1690 (0.1186)	0.0391 (0.1639)	-0.4187 (0.2742)	0.0273 (0.1501)
Labour availability [adults > 15yrs/ha]	0.0501* (0.0277)	0.0970** (0.0380)	0.0769* (0.0405)	0.0061 (0.0339)
Off-farm income [%]	-0.0057** (0.0024)	-0.0065** (0.0029)	-0.0071* (0.0039)	-0.0010 (0.0034)
Log credit limit, deflated [000VND]	0.0549 (0.0660)	0.2577*** (0.0633)	0.1371 (0.1229)	-0.0355 (0.0735)
Log value cattle/buffalo, deflated [000VND]	0.0165** (0.0077)	0.0227* (0.0120)	0.0111 (0.0206)	0.0399** (0.0153)
HH with good extension access in village [%]	0.1301 (0.3241)	0.3292 (0.2950)	0.2458 (0.4949)	0.5959 (0.5552)
Paved road distance [walking min]	-0.0025 (0.0029)	0.0011 (0.0023)	-0.0063*** (0.0021)	-0.0033 (0.0030)
HH is poor [1=poor]	-	-	-	-
Tobit-residual HH maize share	-0.0010 (0.0033)	-0.0033* (0.0019)	-0.0131*** (0.0024)	-0.0091* (0.0048)
Constant	8.0600*** (0.7040)	5.5053*** (0.6164)	6.0657*** (1.5368)	8.7545*** (0.8059)
Observations	88	90	88	87
R-squared	0.5833	0.5280	0.4542	0.2399
Adj_R2	0.5034	0.4399	0.3495	0.0920
Prob > F	0.0000	0.0000	0.0000	0.0003

Robust standard errors in parentheses, clustered at village level (*** p<0.01, ** p<0.05, * p<0.1)

Source: Own data

Table 4-4: Regression results – Non-Poor households

VARIABLES	(M3.1) 2007 Non-poor	(M3.2) 2008 Non-poor	(M3.3) 2009 Non-poor	(M3.4) 2010 Non-poor
Farm area, value adjusted [million VND m²]	-0.0030 (0.0026)	-0.0076** (0.0031)	0.0010 (0.0046)	-0.0037 (0.0042)
Log land value upland [VND/m²]	0.1239** (0.0454)	0.1551** (0.0564)	0.2220*** (0.0720)	0.0805 (0.0581)
Age HH head [years]	-0.0085*** (0.0026)	-0.0030 (0.0027)	-0.0065 (0.0038)	-0.0034 (0.0034)
Education HH head [years]	0.0008 (0.0093)	0.0013 (0.0085)	0.0071 (0.0138)	0.0197 (0.0143)
Sex HH head [1=male]	0.1549* (0.0873)	0.0993 (0.1037)	0.0234 (0.1115)	-0.0126 (0.2397)
Ethnic group HH head [1=Hmong]	-	-	-	-
Ethnic group HH head [1=Kinh]	0.3498*** (0.1080)	0.2679** (0.1177)	0.1861 (0.1656)	0.0844 (0.1288)
Labour availability [adults > 15yrs/ha]	0.0253 (0.0148)	0.0343** (0.0147)	0.0701*** (0.0147)	0.0085 (0.0206)
Off-farm income [%]	-0.0032** (0.0014)	-0.0020 (0.0015)	0.0004 (0.0014)	-0.0008 (0.0021)
Log credit limit, deflated [000VND]	0.0700 (0.0444)	0.0928* (0.0488)	0.1288* (0.0640)	0.0455 (0.0527)
Log value cattle/buffalo, deflated [000VND]	-0.0105 (0.0129)	-0.0070 (0.0083)	0.0108 (0.0107)	0.0405* (0.0221)
HH with good extension access in village [%]	-0.1122 (0.1800)	-0.1865 (0.1156)	-0.1995 (0.2534)	0.0548 (0.2177)
Paved road distance [walking min]	-0.0044 (0.0035)	0.0003 (0.0017)	-0.0010 (0.0044)	0.0014 (0.0032)
HH is poor [1=poor]	-	-	-	-
Tobit-residual HH maize share	-0.0043** (0.0017)	-0.0052*** (0.0015)	-0.0130*** (0.0017)	-0.0040 (0.0025)
Constant	8.8092*** (0.5631)	7.8876*** (0.5696)	6.8531*** (0.7094)	8.3813*** (0.7420)
Observations	181	177	171	176
R-squared	0.2481	0.2387	0.3080	0.0994
Adj_R2	0.1896	0.1780	0.2507	0.0271
Prob > F	0.0000	0.0002	0.0000	0.0261

Robust standard errors in parentheses, clustered at village level (*** p<0.01, ** p<0.05, * p<0.1)

Source: Own data

4.4.2. Explanation and discussion of decomposition results

In the final step of the analysis, we run an Oaxaca-Blinder decomposition for each of the years 2007 to 2010.

Table 4-5 shows the summary of the decomposition results. The first and second lines show the predicted values of net maize income per hectare for the poor (Prediction poor) and the non-poor (Prediction middle & wealthy). The third and fourth lines show the estimated total difference in net maize income per hectare (henceforth maize income gap) between the poor and the non-poor based on the maize share self-selected unadjusted regressions (Total difference) and adjusted regressions (Total adjusted difference). The unadjusted decompositions are based on the plain regression results without the Tobit-residual included, while the adjusted decompositions are based on the regressions that include the Tobit-residual from the Tobit selection model (household characteristics on maize share) (Wooldridge, 2012). The fifth and sixth lines show the estimates for the share of the total adjusted difference of the maize income gap that can be explained by the poor and non-poor groups' differences in asset endowments (asset-based share) as well as the share of the total adjusted difference of the maize income gap that can be explained by the poor and non-poor groups' differences in returns to asset endowments (return-based share).

Looking first at the differences between the unadjusted and adjusted decomposition models, the maize income gap is slightly larger when the adjusted decomposition models compared to the unadjusted models are used. Using the adjusted decompositions increases the maize income gap by 0.64% (0.0064 log points) in 2007, 1.05% (0.0105 log points) in 2008, 2.18% (0.0216 log points) in 2009, and 0.71% (0.0071 log points) in 2010. Hence, not including the Tobit-residuals slightly underestimates the maize income gap between the poor and the non-poor. Since the coefficients of the Tobit-residuals are negative in the underlying OLS regressions of the poor and the non-poor (Table 4-3, Table 4-4), the maize income of the poor seems to suffer slightly more from increased maize share than the maize income of the non-poor. Since maize is a fertiliser intensive crop and the poor use fewer inputs already, financial or labour constraints could be relatively more binding for the poor when increasing maize share if using more fertiliser and labour on smaller areas increases the efficiency of maize production (Rusinamhodzi et al., 2016). However, the bias between the two models is very small overall.

Table 4-5: Summary Oaxaca-Blinder decomposition results

		(D1) 2007		(D2) 2008		(D3) 2009		(D4) 2010	
VARIABLES	**Measurement scale**	**Value**	**Sig**	**Value**	**Sig**	**Value**	**Sig**	**Value**	**Sig**
Prediction middle & wealthy	Log points	9.813	***	9.512	***	9.494	***	9.684	***
	SD (Log points)	(0.044)		(0.029)		(0.055)		(0.042)	
	VND	18,269		13,519		13,281		16,057	
Prediction poor	Log points	9.484	***	9.152	***	9.204	***	9.529	***
	SD (Log points)	(0.094)		(0.085)		(0.108)		(0.078)	
	VND	13,150		9,453		9,934		13,749	
Total difference	Log points	0.329	***	0.360	***	0.290	**	0.155	*
	SD (Log points)	(0.097)		(0.088)		(0.117)		(0.087)	
	%	38.9		43.3		33.7		16.8	
Total adjusted difference	Log points	0.335	***	0.370	***	0.312	***	0.162	*
	SD (Log points)	(0.097)		(0.090)		(0.119)		(0.085)	
	%	39.8		44.8		36.6		17.6	
Asset-based share of difference	Log points	0.237	**	0.275	***	0.233	**	0.113	
	SD (Log points)	(0.104)		(0.064)		(0.108)		(0.080)	
	% Raw share	26.7		31.7		26.2		12.0	
	% In total difference	70.6		74.4		74.7		69.5	
Return-based share of difference	Log points	0.098		0.095		0.079		0.049	
	SD (Log points)	(0.083)		(0.084)		(0.118)		(0.086)	
	% Raw share	10.3		9.9		8.2		5.1	
	% In total difference	29.4		25.6		25.3		30.5	
Observations		269		267		259		263	

Robust standard errors in parentheses, clustered at village level (*** $p<0.01$, ** $p<0.05$, * $p<0.1$)

Source: Own data

Continuing with the adjusted models only for the remainder of the chapter, the size of the maize income gap between the poor and the non-poor is except for 2010 quite consistent and for all years statistically significant over time. The maize income gap accumulated to 39.8% (0.335 log points) in 2007 [p<0.01], 44.8% (0.370 log points) in 2008 [p<0.01], 36.6% (0.312 log points) in 2009 [p<0.01], and 17.6% (0.162 log points) [p<0.1] in 2010, respectively. Hence, crop income gaps between the poor and the non-poor as the descriptives in chapter 2 already show can be significant. The smaller value of the maize income gap in 2010 follows the rationality that the non-poor lose relatively more than the poor in the case of crop failure. Since the non-poor's input investments are higher, the non-poor experience larger financial losses (i.e. sunk costs) in the case of drought, which reduces the non-poor's maize incomes relatively more than the maize incomes of the poor, which most likely contributes to narrowing the maize income gap.[58] The lower overall significance levels of the 2010 decomposition model as well as the lower explanatory power and significance of the underlying OLS models from 2010 support that perspective.

Considering the distribution of the total maize income gap between asset-based and return-based effects, in all years the asset-based effects dominate and are consistently significantly different from zero other than 2010. Overall, the asset-based effects account for 70.6%, 74.4%, 74.7%, and 69.5% of the total maize income gap in the years 2007 to 2010, respectively. If the poor would have the same asset endowments as the non-poor, then their net maize income per hectare would be higher in absolute numbers by 26.7% (0.237 log points) [p<0.05] in 2007, 31.7% (0.275 log points) [p<0.01] in 2008, 26.2% (0.233 log points) [p<0.05] in 2009, and 12.0% (0.113 log points) [ns] in 2010. On the contrary, the return-based effects contribute only 29.4%, 25.6%, 25.3%, and 30.5% to the maize income gap from 2007 to 2010. In terms of absolute numbers, if the poor would have the same coefficient structure as the non-poor group, their net maize income per hectare would increase by 10.3% (0.098 log points) [ns] in 2007, 9.9% (0.095 log points) [ns] in 2008, 8.2% (0.079 log points) [ns] in 2009, and 5.1% (0.049 log points) [ns] in 2010. However, the return-based effects are not statistically significant in any of the years.

These results are in contrast to Oaxaca-Blinder decomposition analyses for total per-capita income and per-capita consumption measurements that frequently find both statistically significant asset- and return-based effects on income (consumption) gaps between ethnic minority and majority households in the range of 35.7-57.1% for the asset-based and 64.3-42.9% for the return-based effects depending on type and year of analysis (Baulch et al., 2012; Nguyen et al., 2017), and of the size of 50.2% (49.8%) for the asset- (return-) based effects for the total income gap between ethnic minorities of the Northern Uplands and minorities in other regions of Vietnam (Nguyen et al., 2017). Hence, our results are somewhat in contrast to the overall picture that shows substantial return-based effects in OB-decompositions based on total per-capita income or consumption. Considering single income sources, such as maize income alone, the distribution of asset- to return-based effects may be quite different. Reasons for this may include, that firstly, and as already mentioned before, maize production can be considered well-established. Hybrid maize cultivation with additional mineral fertiliser inputs has been introduced and promoted since the 1990s (Thanh et al., 2004; Thanh and Neefjes, 2005).[59] Return-based differences in productivity that may originate from differences

[58] Average maize yields of the poor is 5.9% lower in 2010 compared to their average maize yields in 2007 to 2009 (difference statistically not significant), while average maize yields of the non-poor in 2010 is 17.2% lower compared to their average maize yields of 2007 to 2009 [p<0.01]. At the same time, net maize income per hectare is higher in 2010 compared to the average of net maize incomes in 2007 to 2009 in all household groups (because of the higher output prices in 2010), but net maize income per hectare of the poor is 21.0% higher in 2010 than their average net maize income per hectare of 2007 to 2009 [p<0.01], while for the non-poor net maize income per hectare is only 6.9% higher in 2010 than the average of 2007 to 2009 [p<0.1].

[59] Mineral fertilisers as such were known already during the cooperative period. However, intensification efforts were restricted to the cooperatives in the upland's lowland valleys producing paddy rice. Moreover, paddy

in human capital variables, such as age, knowledge, and gender, may have vanished through the increase of experience and the exchange of knowledge over time (Foster and Rosenzweig, 1995). In this respect, To-The and Nguyen-Anh (2020) find in a study, that compares technical efficiency of maize production in terms of yield in a sample of maize farmers in the Northern Uplands, that participation in extension does indeed have the potential to annihilate the impact of human capital variables, such as age, gender, and education, on the outcome of technical efficiency in maize production. In particular, they find that the variables of age, gender, and education have no significant impact on the efficiency of maize production in the household group that received extension, but that the impact of the same variables is significantly different and positively correlated with the efficiency of maize production for the households that did not receive extension.[60] This is also confirmed by the results of our underlying OLS regressions, which also find little evidence for the impact of the age, education, and gender variables on maize income. Hence, extension as well as the long-term establishment may have a decreasing effect on the impact of knowledge-related human capital variables on agricultural productivity and therefore return-based effects. Secondly, the aforementioned studies on the decomposition of total income and consumption expenditure gaps between ethnic minority and majority groups into asset- and return-based effects also show that regarding return-based effects, across location differences can be higher than within locations differences (Van De Walle and Gunewardena, 2001), and that a large share of return-based effects may come from the large differences in education levels and the high returns household with high education can generate from acquiring and pursuing off-farm jobs (The World Bank, 2012; Van De Walle and Gunewardena, 2001).

Table 4-6 to Table 4-9 show the results of the detailed decomposition analysis, which lists how much the endowment with each single asset type ("detailed asset-based shares") and the return of each single asset type ("detailed return-based shares") contribute to the total maize income gap separately. Since the overall share of the asset-based component is statistically significantly different from zero only, the following discussion focuses on the detailed decomposition for the asset-based share. Moreover, the total sum of the asset-based component was not significantly different from zero in 2010, too. We therefore only mention

---

rice production in the cooperatives often suffered from the limited actual availability of mineral fertilisers and low actual productivity increases. Upland agriculture during the same period was organized privately within traditional swidden farming systems. Hence, maize intensification started with the Doi Moi reforms and the promotion of hybrid seeds and mineral fertilisers for maize production in the 1990s (Hossain and Singh, 2000; Sadoulet et al., 2002; Thanh et al., 2004).

[60] In more detail, the study from To-The and Nguyen-Anh (2020) considered two periods (2010, 2015) for two household groups (households that received extension, and household that did not). In the first period (2010) before any group received extension, age, education, and gender was mostly insignificant in the inefficiency models for any of the two household groups. In the second period (2015), after one group received extension and the other not, the technical efficiency score increased in both household groups, from 0.87 to 0.96 in the group that received extension and from 0.75 to 0.88 in the group that did not receive extension. However, the age, education, gender variables were all insignificant in the inefficiency model of the household group that received extension and all significantly different from zero in the inefficiency model of the households that did not receive extension.

the 2010 part briefly in the discussion of the detailed decomposition results given that the single asset-based component is statistically different from zero in the detailed decomposition. Positive (negative) values mean that the respective asset type increases (decreases) the maize income gap by the respective amount measured in log points (first column, “Log points”) and in percentage (second column, “%”).

Considering the “detailed asset-based shares” of the decomposition analysis shows that differences in the asset levels of upland land value, whether the household head is ethnic Hmong, the amount of credit limit of the household, and the value of cattle and buffalo have all a significant increasing effect on the maize income gap. Asset-based differences in value adjusted farm area and the age of the household head have a significant decreasing effect on the maize income gap.

The impact of the household head being Hmong is large and significantly different from zero widening the maize income gap by 14.3% (0.134 log points) [p<0.05] in 2007 and 9.3% (0.089 log points) [p<0.05] in 2008, small and not significantly different from zero in 2009 (2.6% (0.026 log points), [ns]), and having a small decreasing but insignificant impact on the maize income gap in 2010 (-1.9% (-0.019 log points), [ns]). Differences in maize incomes between ethnic groups seem to be diminishing in the research area over the period, perhaps because of an extended spread of cultivation practices towards higher input use intensity (Kyeyune and Turner, 2016) (see also chapter 2). Many studies find that there are differences in farming habits between ethnic groups driven by location, differences in agroecological environments, and cultural habits (Kyeyune and Turner, 2016; Michaud et al., 2002; Tran, 2003; Van De Walle and Gunewardena, 2001). In particular, the Hmong, who often live in the very high altitudes of the Northern Uplands (Michaud et al., 2002), are one of the ethnic groups that tend to have a propensity to keep more to traditional live styles and farming practices (Kyeyune and Turner, 2016; Van De Walle and Gunewardena, 2001). However, our research also shows that such differences in terms of crop income do not have to be persistent.

Differences in the quantity of household credit limit between the poor and the non-poor are the other large and increasing asset-based factor widening the maize income gap. Credit limit increased the maize income gap by 7.1% (0.068 log points) [p<0.05] in 2007, by 17.8% (0.164 log points) [p<0.01] in 2008, by 12.2% (0.115 log points) [p<0.05] in 2009. The effect of credit limit is insignificant (2.9% (0.029 log points), [ns]) in 2010. The larger impact in 2008 and 2009 compared to 2007 may originate from increasing financing costs because of increases in input prices (chapter 2). Hence, increasing input costs seem to widen the maize income gap between the poor and the non-poor. The insignificant effect in 2010 can most likely be attributed to the drought in 2010 since the additional credit limit that allows households to buy more fertiliser could not optimally translate into additional yield. As already mentioned before, these results are in line with other studies that show that lack of financial access can lead to crop productivity differences between households, like Luan and Bauer (2016) that find a positive impact of credit market participation on farm income for ethnic minority households, and Luan and Kingsbury (2019) that find a positive impact of credit market participation on bamboo income.[61] Moreover, Saint-Maracy (2014) finds similar to our study not only that poor households have lower credit access than the non-poor, but that the poor spend of the total amount of credit received a lower share on agriculture and a higher share on consumption expenditures, such as food, social events, and other emergencies, than the non-poor.[62] Additional to these research, our results show not only a positive impact of credit access on net maize income per hectare based on OLS regressions, but that differences in credit access between the poor and the non-poor are a major driver of the net maize income gap per hectare between the poor and the non-poor based on the decomposition analysis. Hence, the poor depend more on credit for purchasing inputs than the non-poor (chapter 2), and they face a lower credit limit that increases the productivity gap between them and the non-poor.

Asset-based differences in upland land value have a small significant impact on increasing the maize income gap. In 2007, differences in upland land value between the poor and non-poor increase the maize income gap by 2.9% (0.028 log points) [p<0.1], in 2008 by 2.9% (0.028 log points) [p<0.1], in 2009 by 2.4% (0.024 log points) [ns], and in 2010 by 1.8% (0.018 log points) [p<0.1]. Given that the raw difference of on average 2.6% in the log upland land value between the poor and non-poor (8.4% for the exponentiated value) (see Table 4-1) leads already to an on average 2.5% increase in the maize income gap, suggest that soil fertility and sustainability questions may want to be stronger considered. While we admit that upland land value is just a proxy for soil fertility, maize production on steep slopes is considered to suffer from severe soil erosion and in consequence from long-term soil fertility problems and decreasing maize yields (Lippe et al., 2011; Tuan et al., 2014; Wezel et al., 2002b). The lower soil fertility of the poor compared to non-poor may moreover not only be a reason why poorer farmers have lower maize income but also why poorer farmers use less fertiliser because lower soil fertility influences the profitability of additional fertiliser negatively (Marenya and Barrett, 2009a, 2009b). Investing more in research and the solutions of such maize related environmental problems to improve long-term economic perspectives and sustainability of upland farming systems may therefore be important.

Other assets that play a minor and less constant role are asset-based differences in the value of cattle and buffalo, which increases the maize income gap by 7.06% (0.068 log points) [p<0.1] in 2008 and by 8.7% (0.083 log points) [p<0.05] in 2010, but is small and insignificant in 2007 (2.7% (0.026 log points), [ns]) and 2009 (2.0% (0.020 log points), [ns]). This effect on the maize income gap is combined with the poor owning very small values in buffalo and cattle in all years. As already mentioned before, the cattle and buffalo values reported by households, translate in below one head of cattle or buffalo for the poor and above one head

---

[61] As mentioned before, the studies from Luan and Bauer (2016) and Luan and Kingsbury (2019) measure the impact of actual credit market participation of households on farm (bamboo) income. Our study uses credit access, that is the total amount household can borrow plus current outstanding debt, whether a household chooses to actually borrow or not (Diagne et al., 2000).

[62] The study on credit access of households in the Northern Uplands from Saint-Macary (2014) uses data from the same sample as in our study based on the year 2007.

in buffalo or cattle in the non-poor group on average (see Table 4-1). Even though the effect of owning cattle and buffalo on the maize income gap is not very consistent, supporting poor households to improve their asset base regarding cattle and buffalo may still be worthwhile given the importance of cattle and buffalo for agricultural production and possibly risk management (Dercon, 2002; Smith, 2008).

Household assets that are significantly different from zero and decrease the maize income gap are differences in the size of value adjusted farm area reducing the maize income gap by 2.4% (-0.024 log points) [p<0.1] in 2007, 3.8% (-0.039 log points) [p<0.01] in 2008, 2.9% (-0.029 log points) [ns] in 2009, 2.4% (-0.024 log points) [p<0.1] in 2010 in favour of the poor. These results can be attributed to the general negative effect of value adjusted farm area on net hectare maize income in the underlying poor, wealthy, and pooled regressions combined with the larger value of adjusted farm area of the wealthy. However, overall the effect is with around 3% rather small. Moreover, Nguyen et al. (2017: 109 & 111) running Oaxaca-Blinder decomposition analysis on total per-capita household income find that the size of per-capita annual cropland has overall a decreasing effect on the total income gap between ethnic minorities in the Northern Uplands and national households (by 9.4% for the asset-based and by 11.9% for the return-based effect) as well as between ethnic minorities in the Northern Uplands and ethnic minority households in other regions of Vietnam (by 9.9% for the asset-based and 28.4% for the return-based effect). Hence, while on a value corrected basis smaller land size mildly favours the poor compared to the wealthier households within the Northern Uplands because of the negative effect of larger land size on productivity and the larger land size of the wealthy, based on the above mentioned literature larger land size is actually relatively positive for closing the overall income gap between households in the Northern Uplands and households in other areas of Vietnam.

Also, asset-based differences in the age of the household head are significantly decreasing the maize income gap by 4.0% (-0.041 log points) [p<0.05] for 2007. For the other years, no significant effect of household head age can be determined. Results like this can be explained when the lower age in the poor compared to the non-poor group is linked with higher innovativeness of the younger household heads. However, the effect is not very persistent.

Assets that contribute to increasing the maize income gap but have small contributions and are not significantly different from zero are the education level of the household head, whether the household head belongs to the ethnic group Kinh, the labour availability of the household, and the distance to the paved road. Household assets that generally decrease the maize income gap but have small contributions and are not significantly different from zero are the sex of the household head, whether the household head belongs to the ethnic group Black Thai, the share of off-farm income, and the share of households with good extension access at the village level.

Table 4-6: Detailed Oaxaca-Blinder decomposition results 2007

	2007							
	(D1.1) Detailed asset-based shares				(D1.2) Detailed return-based shares			
VARIABLES	Log points	Exponent	Exp%	Sig	Log points	Exponent	Exp%	Sig
Total	**0.237 (0.104)**	**1.267 (1.110)**	**26.72 (10.97)**	**	**0.098 (0.083)**	**1.103 (1.086)**	**10.34 (8.63)**	
Farm area, value adjusted [million VND m²]	-0.024 (0.013)	0.976 (1.013)	-2.40 (1.26)	*	0.061 (0.060)	1.062 (1.062)	6.24 (6.21)	
Log land value upland [VND/m²]	0.028 (0.016)	1.029 (1.016)	2.87 (1.64)	*	-0.494 (0.318)	0.610 (1.374)	-38.98 (37.39)	
Age HH head [years]	-0.041 (0.018)	0.960 (1.018)	-4.03 (1.82)	**	-0.188 (0.174)	0.829 (1.190)	-17.10 (18.98)	
Education HH head [years]	0.018 (0.023)	1.019 (1.024)	1.86 (2.37)		-0.064 (0.075)	0.938 (1.078)	-6.17 (7.77)	
Sex HH head [1=male]	0.000 (0.001)	1.000 (1.001)	-0.02 (0.06)		0.171 (0.090)	1.186 (1.094)	18.60 (9.40)	*
Sex HH head [1=female]	0.000 (0.001)	1.000 (1.001)	-0.02 (0.06)		-0.013 (0.008)	0.987 (1.008)	-1.34 (0.81)	*
Ethnic group HH head [1=Thai]	-0.017 (0.020)	0.983 (1.020)	-1.71 (2.05)		-0.084 (0.041)	0.919 (1.041)	-8.09 (4.15)	**
Ethnic group HH head [1=Hmong]	0.134 (0.055)	1.143 (1.056)	14.31 (5.65)	**	-0.064 (0.055)	0.938 (1.057)	-6.19 (5.66)	
Ethnic group HH head [1=Kinh]	0.006 (0.009)	1.006 (1.009)	0.64 (0.87)		0.003 (0.007)	1.003 (1.007)	0.28 (0.69)	
Labour availability [adults > 15yrs/ha]	0.013 (0.010)	1.013 (1.010)	1.30 (1.04)		-0.054 (0.067)	0.947 (1.070)	-5.30 (6.96)	
Share off-farm income [%]	-0.003 (0.012)	0.997 (1.012)	-0.32 (1.19)		0.032 (0.035)	1.033 (1.036)	3.27 (3.56)	
Log credit limit, deflated [000VND]	0.068 (0.032)	1.071 (1.033)	7.05 (3.25)	**	0.145 (0.863)	1.156 (2.371)	15.61 (137.10)	
Log value cattle/buffalo, deflated [000VND]	0.026 (0.031)	1.027 (1.032)	2.66 (3.18)		-0.199 (0.113)	0.819 (1.119)	-18.05 (11.91)	*
HH with good access to extension in village [%]	0.000 (0.002)	1.000 (1.002)	-0.02 (0.20)		-0.169 (0.292)	0,844 (1.339)	-15.56 (33.95)	
Paved road distance [walking min]	0.029 (0.032)	1.030 (1.032)	2.96 (3.25)		-0.020 (0.079)	0.980 (1.082)	-1.98 (8.21)	
Constant					1.037 (1.004)	2.820 (2.729)	182.02 (172.92)	
Observations	269							

Robust standard errors in parentheses, clustered at village level: *** p<0.01, ** p<0.05, * p<0.1

Source: Own data

Table 4-7: Detailed Oaxaca-Blinder decomposition results 2008

VARIABLES	2008 (D2.1) Detailed asset-based shares				(D2.2) Detailed return-based shares			
	Log points	Exponent	Exp%	Sig	Log points	Exponent	Exp%	Sig
Total	**0.275** **(0.091)**	**1.317** **(1.096)**	**31.69** **(9.56)**	***	**0.095** **(0.084)**	**1.099** **(1.088)**	**9.94** **(8.78)**	
Farm area, value adjusted [million VND m²]	-0.039 (0.013)	0.962 (1.013)	-3.84 (1.30)	***	0.027 (0.060)	1.027 (1.062)	2.70 (6.19)	
Log land value upland [VND/m²]	0.028 (0.017)	1.029 (1.017)	2.89 (1.70)	*	-0.093 (0.614)	0.912 (1.847)	-8.85 (84.71)	
Age HH head [years]	0.000 (0.017)	1.000 (1.017)	0.02 (1.75)		-0.170 (0.216)	0.843 (1.241)	-15.67 (24.09)	
Education HH head [years]	0.012 (0.023)	1.012 (1.024)	1.16 (2.36)		-0.058 (0.074)	0.944 (1.077)	-5.62 (7.73)	
Sex HH head [1=male]	-0.001 (0.002)	0.999 (1.002)	-0.08 (0.19)		0.182 (0.089)	1.200 (1.093)	19.95 (9.30)	**
Sex HH head [1=female]	-0.001 (0.002)	0.999 (1.002)	-0.08 (0.19)		-0.014 (0.008)	0.986 (1.008)	-1.35 (0.78)	*
Ethnic group HH head [1=Thai]	-0.026 (0.018)	0.975 (1.018)	-2.53 (1.80)		-0.042 (0.052)	0.959 (1.053)	-4.07 (5.29)	
Ethnic group HH head [1=Hmong]	0.089 (0.043)	1.093 (1.043)	9.29 (4.35)	**	-0.101 (0.062)	0.904 (1.064)	-9.62 (6.44)	
Ethnic group HH head [1=Kinh]	0.006 (0.007)	1.006 (1.007)	0.57 (0.69)		0.008 (0.012)	1.008 (1.012)	0.81 (1.22)	
Labour availability [adults > 15yrs/ha]	0.020 (0.014)	1.020 (1.014)	2.04 (1.40)		-0.135 (0.080)	0.874 (1.083)	-12.64 (8.30)	*
Share off-farm income [%]	-0.002 (0.010)	0.998 (1.010)	-0.17 (1.01)		0.063 (0.044)	1.065 (1.045)	6.50 (4.51)	
Log credit limit, deflated [000VND]	0.164 (0.044)	1.178 (1.045)	17.83 (4.50)	***	-1.631 (0.753)	0.196 (2.122)	-80.43 (112.24)	**
Log value cattle/buffalo, deflated [000VND]	0.068 (0.038)	1.071 (1.039)	7.06 (3.89)	*	-0.237 (0.128)	0.789 (1.137)	-21.09 (13.65)	*
HH with good access to extension in village [%]	0.000 (0.002)	1.000 (1.002)	-0.02 (0.21)		-0.359 (0.222)	0.698 (1.249)	-30.18 (24.88)	
Paved road distance [walking min]	-0.044 (0.032)	0.957 (1.033)	-4.28 (3.30)		0.020 (0.064)	1.020 (1.066)	2.00 (6.63)	
Constant					2.635 (0.843)	13.940 (2.323)	1293.98 (132.35)	***
Observations	267							

Robust standard errors in parentheses, clustered at village level: *** p<0.01, ** p<0.05, * p<0.1

Source: Own data

Table 4-8: Detailed Oaxaca-Blinder decomposition results 2009

VARIABLES	2009							
	(D3.1) Detailed asset-based shares				(D3.2) Detailed return-based shares			
	Log points	Exponent	Exp%	Sig	Log points	Exponent	Exp%	Sig
Total	**0.233**	**1.262**	**26.24**	**	**0.079**	**1.082**	**8.21**	
	(0.108)	**(1.114)**	**(11.37)**		**(0.118)**	**(1.126)**	**(12.55)**	
Farm area, value adjusted [million VND m²]	-0.029	0.971	-2.85		0.332	1.394	39.40	***
	(0.018)	(1.018)	(1.79)		(0.099)	(1.104)	(10.35)	
Log land value upland [VND/m²]	0.024	1.024	2.42		-0.304	0.738	-26.23	
	(0.019)	(1.020)	(1.95)		(0.721)	(2.057)	(105.75)	
Age HH head [years]	-0.020	0.981	-1.94		-0.541	0.582	-41.78	**
	(0.025)	(1.026)	(2.57)		(0.235)	(1.264)	(26.43)	
Education HH head [years]	0.041	1.042	4.20		-0.064	0.938	-6.23	
	(0.034)	(1.034)	(3.42)		(0.122)	(1.130)	(13.03)	
Sex HH head [1=male]	-0.001	0.999	-0.11		0.006	1.006	0.65	
	(0.003)	(1.003)	(0.29)		(0.116)	(1.123)	(12.29)	
Sex HH head [1=female]	-0.001	0.999	-0.11		0.001	1.001	0.11	
	(0.003)	(1.003)	(0.29)		(0.012)	(1.013)	(1.26)	
Ethnic group HH head [1=Thai]	0.012	1.012	1.19		-0.136	0.873	-12.71	
	(0.028)	(1.029)	(2.86)		(0.093)	(1.097)	(9.73)	
Ethnic group HH head [1=Hmong]	0.026	1.026	2.60		-0.094	0.911	-8.93	
	(0.044)	(1.045)	(4.50)		(0.065)	(1.068)	(6.75)	
Ethnic group HH head [1=Kinh]	0.000	1.000	0.04		0.025	1.025	2.48	
	(0.001)	(1.001)	(0.14)		(0.023)	(1.023)	(2.28)	
Labour availability [adults > 15yrs/ha]	0.007	1.007	0.75		-0.015	0.985	-1.53	
	(0.032)	(1.032)	3.22		(0.100)	(1.105)	(10.48)	
Share off-farm income [%]	0.002	1.002	0.17		0.123	1.131	13.06	*
	(0.008)	(1.008)	0.80		(0.074)	(1.077)	(7.68)	
Log credit limit, deflated [000VND]	0.115	1.121	12.15	**	-0.096	0.909	-9.14	
	(0.051)	(1.052)	5.23		(1.355)	(3.876)	(287.59)	
Log value cattle/buffalo, deflated [000VND]	0.020	1.020	2.04		0.009	1.009	0.87	
	(0.037)	(1.037)	3.74		(0.171)	(1.187)	(18.69)	
HH with good access to extension in village [%]	-0.001	0.999	-0.13		-0.252	0.777	-22.26	
	(0.010)	(1.010)	1.00		(0.255)	(1.290)	(28.99)	
Paved road distance [walking min]	0.038	1.039	3.89		0.097	1.102	10.23	
	(0.041)	(1.041)	4.15		(0.085)	(1.088)	(8.82)	
Constant					0.988	2.685	168.49	
					(1.544)	(4.682)	(368.20)	
Observations	259							

Robust standard errors in parentheses, clustered at village level: *** p<0.01, ** p<0.05, * p<0.1

Source: Own data

Table 4-9: Detailed Oaxaca-Blinder decomposition results 2010

VARIABLES	2010 (D4.1) Detailed asset-based shares				(D4.2) Detailed return-based shares			
	Log points	Exponent	Exp%	Sig	Log points	Exponent	Exp%	Sig
Total	**0.113** **(0.080)**	**1.119** **(1.083)**	**11.95** **(8.34)**		**0.049** **(0.086)**	**1.051** **(1.089)**	**5.07** **(8.94)**	
Farm area, value adjusted [million VND m²]	-0.024 (0.013)	0.976 (1.014)	-2.37 (1.36)	*	0.132 (0.092)	1.141 (1.097)	14.07 (9.66)	
Log land value upland [VND/m²]	0.018 (0.011)	1.018 (1.011)	1.78 (1.06)	*	-0.401 (0.520)	0.670 (1.682)	-33.03 (68.21)	
Age HH head [years]	-0.001 (0.022)	0.999 (1.023)	-0.10 (2.27)		-0.277 (0.211)	0.758 (1.235)	-24.21 (23.50)	
Education HH head [years]	0.036 (0.033)	1.036 (1.034)	3.63 (3.35)		0.162 (0.117)	1.176 (1.124)	17.57 (12.37)	
Sex HH head [1=male]	-0.001 (0.003)	0.999 (1.003)	-0.13 (0.33)		0.074 (0.105)	1.077 (1.110)	7.72 (11.03)	
Sex HH head [1=female]	-0.001 (0.003)	0.999 (1.003)	-0.13 (0.33)		-0.007 (0.011)	0.993 (1.011)	-0.73 (1.09)	
Ethnic group HH head [1=Thai]	-0.016 (0.030)	0.984 (1.030)	-1.62 (3.00)		0.007 (0.077)	1.007 (1.080)	0.75 (7.99)	
Ethnic group HH head [1=Hmong]	-0.019 (0.056)	0.981 (1.058)	-1.90 (5.78)		-0.003 (0.036)	0.997 (1.036)	-0.34 (3.62)	
Ethnic group HH head [1=Kinh]	0.000 (0.002)	1.000 (1.002)	-0.01 (0.17)		0.005 (0.009)	1.005 (1.009)	0.51 (0.94)	
Labour availability [adults > 15yrs/ha]	0.004 (0.010)	1.004 (1.010)	0.43 (1.01)		0.006 (0.078)	1.006 (1.081)	0.60 (8.06)	
Share off-farm income [%]	-0.004 (0.007)	0.996 (1.007)	-0.44 (0.72)		0.004 (0.057)	1.004 (1.058)	0.39 (5.83)	
Log credit limit, deflated [000VND]	0.029 (0.035)	1.029 (1.035)	2.92 (3.53)		0.837 (0.831)	2.310 (2.296)	130.96 (129.59)	
Log value cattle/buffalo, deflated [000VND]	0.083 (0.039)	1.087 (1.040)	8.67 (4.03)	**	0.020 (0.205)	1.020 (1.228)	2.00 (22.75)	
HH with good access to extension in village [%]	0.005 (0.011)	1.005 (1.011)	0.50 (1.14)		-0.305 (0.283)	0.737 (1.327)	-26.30 (32.66)	
Paved road distance [walking min]	0.006 (0.034)	1.006 (1.034)	0.59 (3.44)		0.097 (0.073)	1.102 (1.076)	10.16 (7.55)	
Constant					-0.300 (0.959)	0.740 (2.608)	-25.95 (160.80)	
Observations	263							

Robust standard errors in parentheses, clustered at village level: *** p<0.01, ** p<0.05, * p<0.1

Source: Own data

4.5. Summary and implications for research and policy

Agriculture remains one of the most important income sources for the mountain population of Vietnam, particularly for ethnic minorities. While agricultural income inequality contributes little to overall income inequality in the country, differences in agricultural incomes between poor and non-poor households can still be substantial. To support households to increase agricultural productivity, it is important to investigate the sources of these agricultural income gaps. A particularly important question in this respect is what drives crop income differences between the poor and the non-poor. Our analysis of maize income gaps between the poor and non-poor finds that hectare based income gaps in maize are high. They range between 36.6-44.8% for the non-drought years and 17.6% for the drought year. Income differences of this kind may both result from the differences in assets quantity as well as differences in return to assets. The decomposition analysis finds that the larger share of the maize income gap (i.e. 69.5-74.7% depending on the year) can be attributed to asset-based effects, while the smaller share can be attributed to return-based effects (i.e. 25.3-30.5% depending on the year). However, while the asset-based effects were significantly different from zero in all years other than 2010, the drought year when the income gap was low overall, the return-based effects were never significantly different from zero. These results are contrary to research that finds both substantial significant asset- and return-based effects for total income and consumption decompositions relating to ethnic minorities/ethnic majority and ethnic minorities in the Northern Uplands/ethnic minorities in other areas of Vietnam comparisons (Baulch et al., 2012; Nguyen et al., 2017). Hence, while overall income and consumption expenditure comparisons across populations of Vietnam can include substantial return-based effects, and agricultural productivity differences may exist between regions (Kompas et al., 2012; Lançon et al., 2014), poor households can nevertheless have the same productive potential related to agricultural activities as the non-poor if they would have the same assets as the non-poor, at least in direct comparison at the regional level. The insignificance of the return-based effects may further originate from the fact that maize is a long introduced and well-established crop. Hybrid maize varieties and mineral fertilisers for maize production have been introduced since the 1990s (Thanh et al., 2004). Therefore, efficiency-based differences in maize production that may result from a lack of knowledge transfer and experience (Foster and Rosenzweig, 1995) between the poor and non-poor may not be existent (Schultz, 1964). This perspective is further supported by a study that compared technical efficiency of maize production in respect to maize yield between households that received and that did not receive government extension on maize cultivation in a sample of farmers in the Northern Uplands. In this study, the authors find that extension can annihilate the impact of household characteristics like age, gender, and education on the efficiency of maize production (To-The and Nguyen-Anh, 2021). Moreover, part of return-based effects in the total income and consumption studies may depend on across-location effects as well as on the strong impact secondary education can have on the access to and the returns from higher-enumerated off-farm employment (The World Bank, 2012; Van De Walle and Gunewardena, 2001). These types of return-based effects may be less relevant for the potential of the poor and non-poor regarding agriculture within regions. In this respect, our results show that the evidence of significant return-based effects in total income and consumption based studies do not have to mean that single income sources have to be affected by it. Poorer households need not to have lower agricultural potential once they have access to the same assets. Hence, supporting poor households to get access and accumulate assets should be an important policy goal.

The detailed decomposition analysis, which analyses which single household assets contribute to the asset-based effect, shows that while many of the asset-based variables are significantly different from zero in the group-wise OLS regressions, the maize income gap is dominated by view variables that have a larger impact only. In the group-wise OLS regressions, i.e. for all households, the poor, and the non-poor, value adjusted farm area, soil quality, ethnicity of the household head, labour availability, share of non-farm income, credit limit, value of cattle and buffalo are significantly different from zero in most years, and age of the household head and distance to paved road are significantly different from zero in some years. In contrast, variables that significantly influence the maize income gap between the poor and non-poor are whether the household head was Hmong, the credit limit of the household, upland land value, value adjusted farm area, and to a lesser extent the value of cattle and buffalo as well as the age of the household head. The largest impacts can be attributed to the ethnicity of the household head (being Hmong) increasing the maize income gap by 14.3% in 2007 and 9.3% in 2008 as well as the credit limit in all years but 2010 increasing the maize income gap by 7.1% in 2007, 17.8% in 2008, and 12.2% in 2009. Smaller impacts are contributed by the upland land value increasing the maize income gap by 2.9% in 2007, 2.9% in 2008, and 1.8% in 2010 as well as the value of cattle and buffalo increasing the maize income gap by 7.1% in 2008 and 8.7% in 2010. Value adjusted farm area has a decreasing impact on the maize income gap by 2.4% in 2007, 3.8% in 2008, and 2.4% in 2010. Age of the household head has a decreasing impact on the maize income gap by 4.0% in 2007.

From these results, we draw the following conclusions. Credit limit constitutes the most important single factor that drives the net maize income gap per hectare. This result is confirmed by studies that show that lack of financial means is an important topic concerning agriculture in the Northern Uplands (Yen et al., 2013), for single crops (bamboo) (Luan and Kingsbury, 2019), the poor in the Northern Uplands (Saint-Macary, 2014), and ethnic minorities in Vietnam (Luan and Bauer, 2016). Our results further show that lack of credit access can directly lead to crop income gaps between the poor and non-poor within regions like the Northern Uplands, and hence contribute to within region inequality of living standards. Lower credit access in combination with the lower ability to accumulate wealth through higher incomes from crop production may further contribute to long-term disparities between the poor and non-poor, such as lack of ability to invest in on-farm and non-farm income diversification and perpetual poverty traps (Luan and Bauer, 2016; Sadoulet et al., 2002; Sikor and Vi, 2005; Zimmerman and Carter, 2003). Hence, more effort is needed to provide especially the poor within rural areas with better credit access. However, doing this should consider not only the supply side but also the special needs of the poor. Any increase in credit access should account for the higher risk aversion and lower risk-bearing capacity of the poor (see also chapter 3) as well as transaction cost issues (Buchenrieder Schrieder and Theesfeld, 2000).[63] This includes measures such as improving the financial literacy of households, giving households the opportunity to borrow for consumption, linking credit with insurance or saving options, decreasing transaction costs and the complications linked with successfully applying for loans, as well as, if possible, developing and training households on innovations, i.e. seed breeds or agricultural managements systems, that have the capacity to lower the downside risks of production (Buchenrieder Schrieder and Theesfeld, 2000; Dercon and Christiaensen, 2011; Emerick et al., 2016; To-The and Nguyen-Anh, 2021; Zeller et al., 1997). Hence, improving financial access for the poor will require much more than just improving physical access to banks, but also to support the development of human capital, innovate the financial tools itself, support research into innovations that reduce downside risk, as well as the restitution of extension systems to link agronomic and financial advice.

Ethnicity of the household head (Hmong) has a less long-lasting impact on the maize income gap. While further evidence on the impact of ethnicity on crop income in the Northern Uplands (Luan and Kingsbury, 2019; Minot et al., 2006) and Vietnam (Doutriaux et al., 2008) is likewise mixed, our study additionally shows that ethnicity-based effects on agricultural productivity do not have to be persistent. Since we control for assets in our regression and decomposition analysis, we conclude that the respective effect of ethnicity may have resulted from differences in location, cultural background, agricultural preferences and farming systems, speed of innovation distribution and innovation acceptance, differences in access to government services, or other forms of ethnic discrimination (Kyeyune and Turner, 2016; Michaud et al., 2002; Tran, 2003; Van De Walle and Gunewardena, 2001). While assets are a determining factor of ethnic differences in Vietnam, as evidenced by higher than average poverty rates among (specific) ethnic groups (chapter 2, The World Bank, 2012) and studies that find a direct negative impact of the lower asset levels of minority households on their household income and consumption (Baulch et al., 2007, 2012; Van De Walle and Gunewardena, 2001), our research also suggests placing more emphasis on the investigation of soft factors that may influence the ability of ethnic minorities to profit from agricultural innovations. In this respect, Bonnin and Turner (2011, 2012) and Kyeyune and Turner (2016) find that the introduction of new agricultural innovations into ethnic minority communities in the Northern Uplands, such as improved hybrid seed and additional mineral fertilisers for maize and rice production, not only brings advantages, such as improved yield potential, but also more complicated livelihood outcomes, such as limited adaptability of the modern seed varieties to the more challenging and diverse agroecological conditions of the Northern mountains, top-down extension approaches with lack of sensitivity towards local needs, higher dependence on markets and agricultural institutions, higher financial livelihood risks, and the threatening of traditional and communal institutions, knowledge, and practices.

[63] Buchenrieder Schrieder and Theesfeld (2000) term this bankability. The impovemnet of bankability includes the reduction of borrower transaction cost as well as the improvement of household risk-bearing capacity (see there, p. 385).

Hence, successful innovation management for the Northern Uplands should also include more research and sensitivity towards the special needs of upland populations to better adjust agricultural innovations to the people and the environment in which it is used.

We also find a consistent impact of the upland land value on the net maize income gap. While the overall impact is small, it was generated by an about as small difference in the asset level of the upland land value between the poor and the non-poor. From this, we conclude that the maize income gap could be susceptible to the quality of environmental assets like soil fertility. Soil fertility is an important factor for the profitability of fertilizer, the yield potential, and the long-term sustainability of maize production. The lower soil fertility of the poor compared to non-poor can therefore not only be a reason why poorer farmers have lower maize income but also why poorer farmers use less fertiliser because using more fertiliser with lower soil fertility would also be less profitable than for the non-poor farmers (Marenya and Barrett, 2009a, 2009b). Which in turn may also decrease the profitability of increased credit availability to the poor. This may be particularly true for any additional production related credit, that directly depends on the sufficient profitability of additional fertilizer use, but less true for consumption credit options, which function is to smooth consumption and the riskiness of maize production. For this reason and given the large environmental consequences maize production on steep slopes can have on erosion, soil fertility, and maize yield in the long term (Lippe et al., 2011; Tuan et al., 2014; Wezel et al., 2002b), we recommend to increase research and extension efforts to improve the long-term sustainability of maize and agricultural production in the Northern Uplands, with a particular focus on the poor that suffer the most from low soil fertility. This includes research into the improvement of the profitability and the risk management of more sustainable cropping choices (Ngoc and Yokoyama, 2019; Sikor and Vi, 2005; Staal et al., 2014), the investigation into economically attractive soil protection measures that minimize the strong competition between field crops and soil protection measures for land and labour (Saint-Macary, 2014), and stronger support towards on- and non-farm income diversification.

We also find a consistent but small impact of value adjusted farm area on decreasing the net maize income gap. While this is in line with the so-called “inverse-farm-size-productivity-relationship”, cross-regional research on total income and consumption shows that larger per-capita land size in fact supports closing the total income gap between minorities in the Northern Uplands and the national comparisons group as well as between minorities in the Northern Uplands and minorities in other regions of Vietnam (Nguyen et al., 2017). Hence, since the effect is small, we recommend not to overemphasize it.

5. Summary

5.1. Introduction

Independent of the tremendous success in agriculture and the wider economy achieved by the Doi Moi reforms, the Northern Uplands, like many upland areas in South East Asia, still struggle with high poverty rates, low agricultural productivity, and increasing environmental degradation (Akramov et al., 2010; Kono and Rambo, 2004; Schreinemachers et al., 2013). While the overall share of agriculture in Vietnam's economy has decreased tremendously, the Northern Uplands are still dominated by agriculture and the poorest and minority households are most dependent on it (GSO, 2007; Thanh and Neefjes, 2005; Tuyen, 2015). At the same time, commercialization and market integration have increased even in the most remote parts of the Northern Uplands, bringing new opportunities as well as new challenges (Schreinemachers et al., 2013). One of these upland crops that has become highly commercialized and specialized in the Northern Uplands is maize, a crop that needs high levels of inputs and is predominantly grown for cash income both from poor and non-poor farmers alike (Keil et al., 2013; Thanh et al., 2004; Thanh and Neefjes, 2005). Maize is grown as the dominant upland crop in many provinces in the Northern Uplands, reaching shares in agricultural land between 11.5% to 60.5% (GSO, 2007). Since poverty levels have remained high and rural infrastructure and private asset levels low, questions arise which consequences this may have for the commercialization and intensification efforts of agricultural households (Minot et al., 2003, 2006; Tuyen, 2015). Recent research on maize production in the Northern Uplands has focused on the rural maize marketing structure (Lançon et al., 2014), factors that drive household maize specialization (Keil et al., 2013), the estimation of average maize income gaps between current farmers' practice and improved practice based on recommended technology (Yen et al., 2013), the technical efficiency of maize production (To-The and Nguyen-Anh, 2021), and maize intensification tendencies on the provincial level (Nguyen, 2017). Yet, detailed analysis on the extent and factors that drive differences in technology adoption, intensification strategies, and livelihood outcomes related to maize production dependent on household wealth is missing. The research of this doctoral thesis seeks to fill these knowledge gaps by investigating the following research topics: (1) the level and short-term changes in agricultural input use and productivity in maize production by household wealth, (2) the impact of risk aversion on fertiliser use in maize production by household wealth, and (3) the impact of household asset levels and the return to assets on productivity differences in maize production between households of different wealth. From this analysis, we attempt to find out more details on the maize intensification process in the Northern Uplands in particular and to draw conclusions for upland intensification processes in general.

To do so, all research in this doctoral thesis is based on analysis that divided households into wealth groups depending on an asset-based indicator derived by principal component analysis

(PCA) (Henry et al., 2003; Zeller et al., 2006). To investigate changes in the variables of interest over time, our analysis runs from 2007 to 2010.

The chapter proceeds as follows: Section 5.2. briefly summarizes the research results of the doctoral thesis by research question and chapter, and Section 5.3. summarizes and highlights the overall research and policy conclusions of the doctoral thesis.

5.2. Summary of main empirical findings of the doctoral thesis

The research of this doctoral thesis is organized around three main research topics concerning how assets and risks influence households' input intensification decisions and productivity of maize production dependent on household wealth.

Chapter 2: Research Topic 1 "Level and short-term changes in agricultural input use and productivity in maize production by household wealth and over time".

The main research hypothesis (Hypothesis 1) in chapter 2 is: "Since households of different wealth have different levels of assets available, their ability to invest in agricultural production as well as their agricultural productivity differs. Households of different wealth may also face different input and output prices due to differences in accessibility or other forms of disadvantages. Production risks taken by households of different wealth may diverge since households with more wealth can afford to invest in riskier agricultural strategies than the less wealthy."

Based on the theoretical framework outlined in chapter 2, extensive descriptive analysis is run on socio-economic household characteristics, farming system characteristics, maize management decisions, input and output prices, and maize productivity depending on household wealth and over the period 2007 to 2010. Analysis is split by household wealth on the theoretical grounds that asset levels not only may impact livelihood choices of households (Scoones, 1998), but that farm production decisions, such as technology adoption and intensification, may bifurcate at some point in the wealth distribution because households may not have enough assets available to adopt certain technologies and intensify below a certain threshold of wealth but instead adopt more conservative, low-risk strategies (Zimmerman and Carter, 2003). Empirically, the analysis is implemented by splitting households into wealth terciles by an asset-based wealth index constructed by PCA analysis (Henry et al., 2003; Zeller et al., 2006).

The research findings from chapter 2 can be summarized the following. The share of ethnic minority households is high, comprising 76.1% Black Thai minority, 14.5% Hmong minority, Sin Mun minority (<1%), and Kho Mu minority (<1%), as well as 9.4% Kinh ethnic majority households. Poverty is not evenly distributed between ethnic groups. Hmong households belong more often (100%) than Black Thai (21%) and Kinh (29%) households to the poorest than to the middle and wealthiest terciles. Households are highly dependent on upland agriculture (71-82%), maize cultivation (69-84%), and maize commercialization in cash income (58-74%), the poorest tercile slightly more than all other households (see also, Keil et al., 2013). Somewhat contrary to research hypothesis 1, we find that the poorest invested similarly strong in the adoption of improved maize varieties (MVs) and mineral fertilisers as the middle and wealthiest terciles, particularly over time. While in 2007 still some differences between wealth terciles regarding the adoption of the seed variety mix and the frequency of mineral fertilisers exist, by 2010 households in all wealth terciles adopt an equal seed mix and with the same frequency mineral fertilisers. Further, households from all wealth terciles switch from using high shares of local improved maize varieties (i.e. 49% LVN10) in 2007 to using higher shares of foreign improved maize varieties (i.e. 49% NK varieties and 36% other MVs) in 2010.[64] The wealthier households switch however seed varieties and reach full fertiliser application rates (i.e. 100%) sooner than the poorest tercile. In line with research hypothesis 1, we find substantial differences in respect to fertiliser intensification levels between the poorest and the wealthier terciles. At recommended fertiliser application levels of 1040-1220 kg/ha (Staal et al., 2014), the poorest apply on average 55% (2007), 70% (2008), 70% (2009), and 79% (2010) of the recommended fertiliser quantities, while the middle and wealthiest terciles apply fertiliser quantities close to the recommended level (94-105%, 2007-2010) with little variation across years. The data further suggest that a higher share of the poorest (51-69%) than the middle and wealthiest terciles (27-50%) underuses fertiliser, while at the same time a respective share of households in all wealth terciles (7-29%) overuses fertiliser. In terms of financial incentives, we find that distance measures are hardly correlated with seed input prices, clearly correlated with fertiliser prices, and arbitrarily correlated with maize output prices. Despite these distance-related impacts, direct comparisons of seed input, fertiliser input, and fertiliser output prices separated by variety type, fertiliser type, and purchasing arrangement, i.e. whether the household purchased directly or on-loan, are not consistently related to household wealth. However, in all years from 2007 to 2010, a higher share of the poorest (64-88%) compared to the middle and wealthiest terciles (23-62%) uses loans to finance seed and fertiliser inputs. In consequence, the poorest households face higher relative input prices. Given on average 17-21% higher on-loan input prices, the poorest pay 14-17% higher prices per unit seed input and 6-13% higher prices per unit fertiliser input for the same seed and fertiliser mix than the middle and wealthiest terciles. Output prices on the other hand are not consistently different between households of different wealth. In consequence, and in line with research hypothesis 1, maize yields are lower in the poorest tercile by 28-33% (2007), 24-28% (2008), 25-35% (2009), and insignificantly different in the drought year 2010, and net maize incomes are lower in the poorest tercile by 33-40% (2007), 31-42% (2008), 13-31% (2009), and insignificantly different in 2010 compared to the middle and wealthiest terciles that reach average maize yields of 7.5-8.2 t/ha in 2007-2009 (6.5 t/ha in 2010) and average net maize incomes of 13.9-20.4 million VND/ha (1850-2713 USD 2011

[64] Other MVs includes all varieties other than LVN10 only and NK varieties only but also mixes of LVN10 and NK varieties with other varieties.

PPP/ha) in 2007-2009 (17.4-18.2 million VND, 2308-2419 USD 2011 PPP/ha in 2010). Contrary to research hypothesis 1, we find that despite the lower input use intensity of the poorest, the poorest households suffer stronger from agricultural price and production risks. The coefficients of variation for maize yields, maize output prices, and maize incomes reach 30%, 29%, 45% in the poorest compared to 25%, 24-25%, 36-38% in the middle and wealthiest terciles, respectively.

Chapter 3: Research Topic 2 “Impact of risk aversion on fertiliser use in maize production by household wealth”

The main research hypothesis (Hypothesis 2) in chapter 3 is: “Since ensuring minimum consumption and protecting vital assets is an important livelihood goal of households (Alderman and Paxson, 1992; Zimmerman and Carter, 2003), individual risk aversion has a larger effect on the fertiliser input decisions of poorer households that are closer to the minimum consumption level than on the fertiliser input decisions of wealthier households that more easily can cover potential shortfalls in crop output by drawing from their stock of wealth. We expect that the effects of risk aversion on fertiliser use by household wealth are independent of the type of wealth and fertiliser measures used.”

Based on the theoretical framework outlined in chapter 3, we test empirically which impact risk aversion has on the fertiliser use of households of different wealth levels applying OLS regression analysis. Risk aversion is included in the form of variables that measure households, i.e. household heads, individual response to a risk self-assessment scale (DIW Berlin) and a lottery game (Holt and Laury, 2002), which is interacted with the households’ wealth index derived by PCA used throughout this thesis (Henry et al., 2003; Zeller et al., 2006). The risk aversion measures are collected by Nielsen et al. (2013). The analysis uses the data on household fertiliser quantity applied from chapter 2 for the year 2010, the year risk aversion variables are collected for.

In line with research hypothesis 2, the results find that the effect of risk aversion on fertiliser use is dependent on household wealth, irrespective of the risk aversion measure, the fertiliser type, and wealth measure used. Fertiliser quantity applied by the poorest one-third of farmers is negatively affected by their level of risk aversion, while risk aversion has no significant effect on the fertiliser quantity applied by farmers of higher wealth regardless of the risk aversion measure used, i.e. the self-assessment scale or the lottery game. For the poorest one-third of farmers and depended on the wealth level of each household an increase of one unit at the risk aversion scale (0-10; 0-9) decreases fertiliser use by 30-200 kg/ha and by 70-350 kg/ha based on the self-assessment scale (0-10) and the lottery game (0-9). A reduction of fertiliser application of 30-350 kg/ha is equivalent to 3-32% of the mean fertiliser use intensity in the area. The results also hold, when instead of total fertiliser quantity applied, NPK quantity, urea quantity, or nitrogen content is used as the dependent variable. Risk aversion has a negative and statistically significant effect on fertiliser use for the poorest one-third of farmers and an insignificant effect on farmers with higher wealth. Considering different measures of wealth, i.e. the asset-based wealth index, household per-capita income, and household per-capita expenditure, we find that the share of households for which risk aversion has a significant negative effect is similar when the wealth index and household consumption expenditures are considered, i.e. 32% and 35%, respectively, and significant but lower when household income is considered, i.e. 9%. For households with higher wealth, the impact of risk aversion on fertiliser use remains insignificant for all wealth measures.

Chapter 4: Research Topic 3 "The impact of household asset levels and asset returns to the productivity gap in maize production between households of different wealth levels".

The main research hypothesis (Hypothesis 3) in chapter 4 is: "Assets as well as return to assets have an important effect on the maize income gap between households of different wealth. Different types of assets as well as different types of return to assets are differently important for the maize income gap."

Based on the theoretical framework outlined in chapter 4, the chapter analyses how differences in the level and the return of household assets contribute to differences in maize incomes between poor and non-poor farmers. For this, we run a decomposition analysis based on a method initially proposed by Blinder (1973) and Oaxaca (1973). The net maize income gap is decomposed into its asset-based (i.e. asset quantity) and return-based (i.e. asset return) components between households in the lowest wealth third of maize farmers, i.e. poor, and households from the highest wealth two-thirds of maize farmers as, i.e. non-poor, as specified by the PCA derived asset-based wealth index (Henry et al., 2003; Zeller et al., 2006) used throughout the doctoral thesis. The decomposition further differentiates between the aggregated and the single (by single asset type) contributions of the asset-based and return-based effects to the maize income gap. The analysis is run on the net maize income data from chapter 2 for the years 2007 to 2010.

At a maize income gap of 39.8%, 44.8%, 36.6%, and 17.6% between poor and non-poor maize farmers, the aggregated decomposition results find that the larger share of the net maize income gap, i.e. 70.6%, 74.4%, 74.7%, and 69.5%, can be attributed to asset-based effects and the smaller share, i.e. 29.4%, 25.6%, 25.3%, and 30.5%, can be attributed to return-based effects for the years 2007 to 2010. In line with research hypothesis 3, we find that the asset-based effects are significantly different from zero in all years other than in the drought year 2010 when the net maize income gap is low overall. In contrary to research hypothesis 3, we find that the return-based effects are never significantly different from zero. Hence, the agricultural productivity differences between the poor and non-poor households are driven by the asset-based effects only, while return-based effects are insignificant.

In this respect, the detailed decomposition analysis, which analyses which single household assets contributed to the asset-based effect, finds that the types of assets that contribute the most to the maize income gap are credit limit, ethnicity of the household head (Hmong), and upland land value. Credit limit has a significant increasing impact on the net maize income gap of 7.1% in 2007, 17.8% in 2008, 12.2% in 2009, and an insignificant impact of 2.9% in the drought year 2010. Whether the household head is Hmong has a significant increasing impact on the net maize income gap by 14.3% in 2007 and 9.3% in 2008, and an insignificant impact of 2.6% in 2009 and -1.9% in 2010. Upland land value has a significant increasing impact of 2.9% in 2007, 2.9% in 2008, an insignificant effect of 2.4% in 2009, and a significant increasing effect of 1.8% in 2010. While the overall impact of the upland land value is small, it is generated by an about as small difference in the respective upland value between the poor and the non-poor. Variables with lower and less consistent significant impacts on the maize income gap are value adjusted farm area, age of the household head, and value of cattle and buffalo. All other variables included in the decomposition models, i.e. education of the household head, sex of the households head, labour availability, share of off-farm income, share of households with good extension access in the village, and distance from paved road, are not significantly different from zero in any of the years.

5.3. Overall discussion and policy conclusions of the doctoral thesis

5.3.1. Improving the scope and quality of research and extension

As the results of this doctoral thesis show, average numbers on technology adoption, intensification levels, yields, and maize income can hide important wealth-related differences and may therefore lead to an overly optimistic look on actual development progress and oversimplified extension messages. We find (chapter 2) that average numbers may, on the one side, overlook obstacles the poorest face to intensify agricultural production as well as, on the other side, ignore the special challenges the less poor households face, such as the possibility to overuse fertilisers once households gain access to sufficient financial means (Nguyen, 2017). In consequence, research and extension messages that focus on average numbers may lead simultaneously to the perpetuation of poverty traps, increased inefficiency, and waste of resources. Therefore, (#1) research and extension should put more emphasis on wealth-related analysis and advice that supports identifying bottlenecks households face dependent on their wealth level. Another aspect identified, is the differentiation between physical and financial availability (chapter 2,3,4). While inputs may be physically available at the same level, given the lower credit limit and the higher propensities of the poorest to take out loans, effective credit access, financial incentives, and risk attached to financing inputs may still be different even when direct prices are the same. Therefore, (#2) research and extension should put more emphasis on wealth-related links between agronomic, financial, and risk-related aspects of agricultural production and improve research designs and extension messages accordingly. This also includes improving research and extension to better account for the efficient use of inputs given the possibly limited extent of the profitability of additional credit and input use and the vast variation of fertiliser application levels between households. The findings also show that the relationship between poverty, ethnicity, and maize income are quite complex. While certain ethnic groups, i.e. the Hmong, are more often poor than others, i.e. the Black Thai and the Kinh (chapter 2), we find a decreasing impact of ethnicity on the maize income gap in the maize income decompositions (chapter 4). Since geographic and agroecological environments, cultural backgrounds, agricultural preferences and farming systems, access to government services, and possibly other factors differ between ethnic minorities within the Northern Uplands (Kyeyune and Turner, 2016; Michaud et al., 2002; Tran, 2003; Van De Walle and Gunewardena, 2001), more research and extension are needed that incorporates these aspects important for upland minority people. So find Bonnin and Turner (2011, 2012) and Kyeyune and Turner (2016) that the introduction of improved hybrid seeds and additional mineral fertilisers for maize and rice production into ethnic minority communities in the Northern Uplands, on the one side, brings advantages, such as improved yield potential, and, on the other side, leads to more complicated livelihood outcomes, such as limited adaptability of the modern seed varieties to the more challenging and diverse agroecological conditions of the Northern mountains, top-down extension approaches with a lack of sensitivity towards the needs of local farming systems and livelihoods, higher dependence on markets and agricultural institutions, lack of sensitivity for food security and subsistence needs of local farmers, higher financial livelihood risks, and the threatening of traditional and communal institutions, knowledge, and practices. Therefore, (#3) research and extension should put more emphasis (a) to disentangle the relationships between minority background, asset levels, poverty, and agricultural productivity and (b) investigate into innovations and agricultural management systems adjusted to the farm systems and needs of upland minorities to be able to better adapt agricultural innovations, extension, and development policies.

5.3.2. Helping poor households to deal with downside risks

Like other studies (i.e. Hardaker et al., 2015; Thulstrup, 2015), we find that households with crop production activities, such as maize, are especially vulnerable to environmental risks, such as yield risks through droughts as well as input and output price risks (chapter 2). While increasing input prices and volatile maize output prices between 2007 and 2010 to some extent may have been a direct effect of increasing and volatile world market prices in that period (Dawe, 2008; Luckmann et al., 2015), other studies reinforce that farming households in the Northern Uplands are indeed very susceptible to decreasing maize output prices (Ngoc and Yokoyama, 2019; Thanh and Neefjes, 2005). Another risk-related problem households may face is uncertainty regarding the quality of fertilisers they use, either because of the risk of buying substandard fertilisers with unknown and possible lower nutrient content than labelled, or because farmers have general doubts about the effectiveness of fertilisers, or they are unfamiliar with the fertilisers quantities needed for their crops (Deng, 2018; Liverpool-Tasie et al., 2010; Nkana, 2016; Phien, 2013; Zahur, 2010). Our analysis (chapter 3) demonstrates theoretically and empirically that households may react differently to such livelihood risks depending on their wealth level since poorer households with incomes closer to minimum consumption needs and lower asset levels may be less able to cover for potential risk-related production shortfalls than wealthier households. In this respect, this thesis finds that the poorest one-third of households suffers more from higher variation in yields, output prices, and net maize incomes than households with higher wealth (chapter 2), and that the input intensification decisions regarding fertiliser quantities used are negatively affected by risk aversion in the poorest one-third of households, while risk aversion has no impact on the fertiliser quantities used by wealthier households. We therefore conclude (#4) that especially for the poorest one-third of households more emphasis should be placed on the expansion of risk management options that account for the lower risk-bearing capacity and higher risk aversion of the poor, the often high transaction costs, and that are based on designs that increase agricultural investment and protect the asset base of households accordingly (Buchenrieder Schrieder and Theesfeld, 2000; Zimmerman and Carter, 2003). Measures should therefore not only include the extension of classical development policies, such as the extension of credit and insurance to the poorest, but put more emphasis on financial innovations that improve the financial literacy of the poor, give households opportunities to borrow for consumption, link credit with insurance or saving options, decrease transaction costs and complications linked with successfully applying for loans, and include financial and risk management advice in extension (Buchenrieder Schrieder and Theesfeld, 2000; Dercon and Christiaensen, 2011; To-The and Nguyen-Anh, 2021; Zeller et al., 1997). Further options include the development of agricultural innovations (i.e. breeds) and management systems that effectively decrease downside production risks for the poorest (Emerick et al., 2016) as well as the development of improved value chains that include crop choices, marketing, and infrastructure innovations that improve households economic security from deteriorating maize output prices, like the production of speciality rice and pig breeds and local branding (Staal et al., 2014).

5.3.3. Acknowledging the importance of assets for agricultural productivity

Based on the decomposition analysis in chapter 4, we find that the lack of assets is the main driver of maize income gaps between the poorest one-third and the wealthier two-thirds of households. These results are in sharp contrast to research that finds both large significant asset-based and return-based effects related to total income and total consumption based decompositions between ethnic minority and ethnic majority households (Baulch et al., 2007, 2012; Van De Walle and Gunewardena, 2001) and related to total income based decompositions between ethnic minority households in the Northern Uplands and in other areas of Vietnam (Nguyen, 2017). Hence, while other research finds that overall income and consumption differences across populations of Vietnam can originate from substantial asset-based and return-based effects and that agricultural productivity differences may exist between regions (Kompas et al., 2012; Lançon et al., 2014), we find that poor households can nevertheless have the same agricultural productive potential as the non-poor if they would have the same assets as the non-poor in direct comparison at the regional level. We therefore

(#5) conclude that closing maize income gaps between poor and non-poor farmers is mainly a matter of supporting poor households to get access and accumulate assets that are the defining drivers of these productivity differences, as in our case credit limit, ethnicity of the household head, upland land value, as well as to a minor extent household head age, value of cattle and buffalo, and value adjusted farm area. While some of these drivers can directly be influenced by policy choices, others can only be influenced indirectly. That credit limit is the most important variable in the decomposition models driving the maize income gap between the poor and the non-poor (chapter 4) strengthens our conclusion from chapter 3 that financial access and risk management are important contributors to intensification in the uplands. A result that is further underpinned by other research that shows that lack of financial means is frequently found to undermine agricultural productivity of Northern upland households and ethnic minorities in Vietnam on the aggregated household level (Luan and Bauer, 2016; Luan and Kingsbury, 2019; Yen et al., 2013). It reinforces our point that especially the poorest lack access to financial tools that help them to invest and insure**.** As mentioned before (i.e. Conclusion #4, above), extending and improving financial access for the poorest should however result in financial innovations that consider the lower risk-bearing capacity and higher risk aversion of the poor, the often high transaction costs, and are based on designs that increase agricultural investment and protect the asset base of households accordingly (see also Buchenrieder Schrieder & Theesfeld, 2000; Dercon & Christiaensen, 2011; To-The & Nguyen-Anh, 2020; Zeller et al., 1997). The importance of household head ethnicity, i.e. being Hmong, in the decomposition models reinforces another point made earlier that more emphasis should be placed on research and extension that incorporate aspects important to upland minority people. While the impact of ethnicity on the maize income gap in the decomposition models is decreasing from high and significant values in 2007 and 2008 to small and insignificant values in 2009 and 2010 (chapter 4), Hmong farmers disproportionally often belong to the poorest tercile (see chapter 2). Thus, while the direct effects of ethnicity on the maize income gap embodied through poverty-associated low asset levels remain valid on the one side (chapter 2), the indirect effects embodied through the ethnicity variables in the decomposition models decrease on the other side (chapter 4). Since ethnic minority backgrounds differ in aspects like location, agroecology, culture and agricultural preferences, farming systems, access to government services, and possibly other factors (Kyeyune and Turner, 2016; Michaud et al., 2002; Tran, 2003; Van De Walle and Gunewardena, 2001), causes for stagnant as well as changing influences of ethnicity on agricultural productivity may be manifold. Consequently and in line with the conclusions made earlier (i.e. Conclusion #3, above), research and extension should put more emphasis (a) to disentangle the relationships between minority background, asset levels, poverty, and agricultural productivity and (b) investigate into innovations and agricultural management systems adjusted to the farm systems and needs of upland minorities to be able to better adapt agricultural innovations, extension, and development policies. From the significance of the upland land value for the maize income gap, we conclude the importance of environmental factors for agricultural productivity. While the overall impact of the upland land value is small, it was generated by an about as small difference in the asset level of the upland land value between the poor and the non-poor (chapter 4). From this, we conclude that the maize income gap could be susceptible to the quality of environmental assets like soil fertility. Soil fertility differences may however impact the quantities of fertilizer application as well as maize income likewise since lower soil fertility reduces the profitability of using fertilizers, which in turn may perpetuate the income differences between the poor and the non-poor (Marenya and Barrett, 2009a, 2009b). The consequences of lower soil fertility on maize income may further be aggravated by the large environmental impact maize production on steep slopes has on erosion and subsequently on soil fertility and maize yields (Lippe et al., 2011; Tuan et al., 2014; Wezel et al., 2002b). We therefore recommend (#6) to increase the research and extension efforts to improve the long-term sustainability of agricultural production in the Northern Uplands. This includes investments in more sustainable production measures, such as more profitable and sustainable cropping choices (Ngoc and Yokoyama, 2019; Sikor and Vi, 2005; Staal et al., 2014), the investigation into more economically attractive soil protection measures that minimize the competition between field crops and soil protection measures for land and labour (Saint-Macary, 2014), and stronger support towards on-farm and off-farm income diversification.

5.3.4. Improving long-term prospects of agricultural production and rural development in the Northern Uplands

In order to effectively combat poverty in the Northern uplands, policy recommendations should also include and define short-term and long-term development goals that cohesively build on each other. In this respect, we recommend (#7) that development policies for the Northern Uplands should focus both on directly improving the conditions for maize productivity and further invest in improved conditions for long-term development, such as the investment in more profitable on-farm and off-farm diversification. Since the profitability of maize production can be crucially endangered by increasing input costs and decreasing maize output prices (Ngoc and Yokoyama, 2019) as well as long-term sustainability concerns (Lippe et al., 2011; Tuan et al., 2014; Wezel et al., 2002b), relying only on high specialization in maize production can be problematic. Yet, on-farm and off-farm income diversification, such as processing and marketing of higher value crops, investments in livestock and perennials, as well as the increase in the share of off-farm employment, require often additional improvement in infrastructure, extension, and accumulation of assets as well. So may other high-value crops than maize still suffer from the relatively underdeveloped infrastructure in the Northern Uplands. Lançon et al. (2014) find that unpaved road connections can generate economically sufficiently low transaction costs to transport maize from upland villages, i.e. a product that is dry, has one harvest per year, and can easily be transported in bulk, but that the same unpaved roads generate transaction costs in access of what is profitable for other high-value crops, such as chilli peppers that have to be harvest and transported weekly and immediately. The same is true for sugarcane, which can be grown in the uplands but needs infrastructure that allows processing within one day and is therefore only an option for villages with all-weather road access and close enough to processing plants (Ngoc and Yokoyama, 2019). Moreover, the low asset levels especially of the poorest may not only impact the current level of maize incomes but also households' future ability to invest in asset-intensive sustainable long-term on-farm and off-farm diversification strategies. Investment capacity especially for on-farm and off-farm diversification and long-term investments will either require the previous built-up of own assets or lending options with longer borrowing periods. So find income diversification studies in the Northern Uplands that wealthier households are stronger diversified than less wealthy households regarding lower maize cash income shares and higher shares of agricultural cash income from sources such as rice, vegetables, fruit trees, and livestock (Keil et al., 2013). Sikor and Vi (2005) find that households with lower assets, labour, and capital are less likely to invest in on-farm and off-farm diversification, while farmers with more accumulated wealth tend to decrease their involvement in maize production in favour of on-farm diversification, such as vegetable farming (low-risk activity) and pig breeding (high-risk activity), as well as off-farm diversification, such as agricultural processing. Additionally, Fatoux et al. (2002) find that the standard 3-year repayment period of bank loans households can acquire in the Northern Uplands are unsuitable for long-term agricultural investments, such as fruit tree plantations (4 to 5 years without income), cow breeding (6 years without income), or timber tree plantations (at least 7 years without income). Lower (agricultural) incomes may further aggravate social disparities by decreasing secondary school enrolment rates and access to health services, while at the same time off-farm diversification requires relevant education and skills (The World Bank, 2012). Hence, supporting poor households to gain access to assets and accumulate household wealth is therefore not only crucial for directly improving agricultural productivity but for supporting households' livelihood options beyond.

References

Ade Freeman, H. and J.M. Omiti (2003) 'Fertilizer Use in Semi-Arid Areas of Kenya: Analysis of Smallholder Farmers' Adoption Behavior under Liberalized Markets', *Nutrient Cycling in Agroecosystems* 66(1): 23–31.

Afidchao, M.M., C.J.M. Musters, A. Wossink, O.F. Balderama, and G.R. De Snoo (2014) 'Analysing the Farm Level Economic Impact of GM Corn in the Philippines', *NJAS - Wageningen Journal of Life Sciences* 70: 113–21.

Akossou, A.Y.J., E.Y. Attakpa, N.H. Fonton, B. Sinsin, and R.H. Bosma (2016) 'Spatial and Temporal Analysis of Maize (Zea Mays) Crop Yields in Benin from 1987 to 2007', *Agricultural and Forest Meteorology* 220: 177–89.

Akramov, K.T., B. Yu, and S. Fan (2010) 'Mountains, Global Food Prices, and Food Security in the Developing World'. International Food Policy Research Institute, Washington, DC.

Alderman, H. and C.H. Paxson (1992) 'Do the Poor Insure? A Synthesis of the Literature on Risk and Consumption in Developing Countries'. The World Bank, Washington, DC.

Alene, A.D. et al. (2008) 'Smallholder Market Participation under Transactions Costs: Maize Supply and Fertilizer Demand in Kenya', *Food Policy* 33(4): 318–28.

Ali, D.A., K. Deininger, and M. Duponchel (2014) 'Credit Constraints and Agricultural Productivity: Evidence from Rural Rwanda', *Journal of Development Studies* 50(5): 649–65.

Alston, J.M., C. Chan-Kang, M.C. Marra, P.G. Pardey, and T.J. Wyatt (2000) 'A Meta-Analysis of Rates of Return to Agricultural R and D Ex Pede Herculem?' International Food Policy Research Institute, Washington, DC.

Alther, C., J.C. Castella, P. Novosad, E. Rousseau, and T.T. Hieu (2002) 'Impact of Accessibility on the Range of Livelihood Options Available to Farm Households in Mountainous Areas of Northern Viet Nam', in J.-C. Castella and D.D. Quang (eds) *Doi Moi in the Mountains Land Use Changes and Farmers' Livelihood Strategies in Bac Kan Province, Viet Nam*, pp. 121–46. Ha Noi, Vietnam: The Agricultural Publishing House.

Anderson, J.R. and G. Feder (2007) 'Agricultural Extension', in R. Evenson and P. Pingali (eds) *Handbook of Agricultural Economics: Agricultural Development - Farmers, Farm Production and Farm Markets*, pp. 2343–78 (Vol. 3). North-Holland.

Andrés, R. et al. (2019) 'Estimating Global Poverty in Stata The Povcalnet Command', Global Poverty Monitoring Technical Note No. 9. World Bank Group.

Angrist, J.D. and J.-S. Pischke (2009) *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, New Jersey: Princeton University Press.

Asfaw, S., F. Di Battista, and L. Lipper (2016) 'Agricultural Technology Adoption under Climate Change in the Sahel: Micro-Evidence from Niger', *Journal of African Economies* 25(5): 637–69.

Asfaw, S., B. Shiferaw, F. Simtowe, and L. Lipper (2012) 'Impact of Modern Agricultural Technologies on Smallholder Welfare: Evidence from Tanzania and Ethiopia', *Food Policy* 37(3): 283–95.

Babcock, B.A. (1992) 'The Effects of Uncertainty on Optimal Nitrogen Applications', *Review of Agricultural Economics* 14(2): 271–80.

Baulch, B., T.T.K. Chuyen, D. Haughton, and J. Haughton (2007) 'Ethnic Minority Development in Vietnam', *Journal of Development Studies* 43(7): 1151–76.

Baulch, B. and E. Masset (2003) 'Do Monetary and Nonmonetary Indicators Tell the Same Story about Chronic Poverty? A Study of Vietnam in the 1990s', *World Development* 31(3): 441–53.

Baulch, B., H.T. Pham, and B. Reilly (2012) 'Decomposing the Ethnic Gap in Rural Vietnam, 1993-2004', *Oxford Development Studies* 40(1): 87–117.

Benjamin, D., L. Brandt, and B. McCaig (2017) 'Growth with Equity: Income Inequality in Vietnam, 2002–14', *Journal of Economic Inequality* 15(1): 25–46.

Berry, W.D., M. Golder, and D. Milton (2012) 'Improving Tests of Theories Positing Interaction', *The Journal of Politics* 74(03): 653–71.

Beyene, A.D. and M. Kassie (2015) ‘Speed of Adoption of Improved Maize Varieties in Tanzania: An Application of Duration Analysis’, *Technological Forecasting and Social Change* 96: 298–307.

Binswanger, H.P. (1981) ‘Attitudes toward Risk: Theoretical Implications of an Experiment in Rural India’, *The Economic Journal*: 867–90.

Birner, R. et al. (2009) ‘From Best Practice to Best Fit: A Framework for Designing and Analyzing Pluralistic Agricultural Advisory Services Worldwide’, *The Journal of Agricultural Education and Extension* 15(4): 341–55.

Blinder, A.S. (1973) ‘Wage Discrimination: Reduced Form and Structural Estimates’, *The Journal of Human Resources* 8(4): 436–55.

Bonnin, C. and S. Turner (2011) ‘Livelihood Vulnerability and Food Security among Upland Ethnic Minorities in Northern Vietnam’, *Philippine Journal of Third World Studies* 26(1–2): 324–40.

Bonnin, C. and S. Turner (2012) ‘At What Price Rice? Food Security, Livelihood Vulnerability, and State Interventions in Upland Northern Vietnam’, *Geoforum* 43(1): 95–105.

Brambor, T., W.R. Clark, and M. Golder (2006) ‘Understanding Interaction Models: Improving Empirical Analyses’, *Political Analysis* 14(1): 63–82.

Brandt, L. and D. Benjamin (2002) ‘Agriculture and Income Distribution in Rural Vietnam under Economic Reforms: A Tale of Two Regions’. The William Davidson Institute, The University of Michigan Business School.

de Brauw, A. (2010) ‘Seasonal Migration and Agricultural Production in Vietnam’, *Journal of Development Studies* 46(1): 114–39.

Buchenrieder Schrieder, G. and I. Theesfeld (2000) ‘Improving Bankability of Small Farmers in Northern Vietnam / Comment Améliorer La “Bancabilité” Des Petits Exploitants Agricoles Du Vietnam Du’, *Savings and Development* 24(4): 385–403.

Carletto, C. (1999) ‘Constructing Samples for Characterizing Household Food Security and for Monitoring and Evaluating Food Security Interventions: Theoretical Concerns and Practical Guidelines’. International Food Policy Research Institute, Washington, DC.

Carletto, C., S. Savastano, and A. Zezza (2013) ‘Fact or Artifact: The Impact of Measurement Errors on the Farm Size-Productivity Relationship’, *Journal of Development Economics* 103(1): 254–61.

Chambers, R. and G.R. Conway (1992) ‘Sustainable Rural Livelihoods: Practical Concepts for the 21st Century’. Institute of Development Studies, University of Sussex, Brighton, United Kingdom.

Chatfield, M. and A.P. Mander (2009) ‘The Skillings–Mack Test (Friedman Test When There Are Missing Data)’, *Stata Journal* 9: 299–305.

Chavas, J.-P. and M.T. Holt (1996) ‘Economic Behavior Under Uncertainty: A Joint Analysis of Risk Preferences and Technology’, *The Review of Economics and Statistics* 78(2): 329–35.

Cheng, Y.S. (1996) ‘A Decomposition Analysis of Income Inequality of Chinese Rural Households’, *China Economic Review* 7(2): 155–67.

Čihák, M., A. Demirgüç-Kunt, E. Feyen, and R. Levine (2012) ‘Benchmarking Financial Systems around the World’. The World Bank, Washington, DC.

CIMMYT (2017) ‘Maize Varieties Grown in SSA’. https://stma.cimmyt.org/maize-varieties-grown-in-sub-saharanafrica/ (accessed 22 October 2020).

Damania, R. et al. (2017) ‘Agricultural Technology Choice and Transport’, *American Journal of Agricultural Economics* 99(1): 265–84.

David, P.A. (1969) ‘A Contribution to the Theory of Diffusion’. Standford Center for Research in Economic Growth, Memorandum No. 71.

Dawe, D. (2008) ‘Have Recent Increases in International Cereal Prices Been Transmitted to Domestic Economies? The Experience in Seven Large Asian Countries’. The Food and Agricultural Organization (FAO), Rome, Italy.

Deininger, K. and G. Feder (2001) ‘Land Institutions and Land Markets’, in B.L. Gardner and G.C. Rausser (eds) *Handbook of Agricultural Economics: Agricultural Production*, pp. 287–331 (Vol. 1, Part A). North-Holland.

Demirgüç-Kunt, A. and L. Klapper (2012) ‘Measuring Financial Inclusion: The Global Findex Database’. The World Bank, Washington, DC.

Deng, S. (2012) '1,700 Arrested in Shoddy Farm Products Crackdown', *Xinhua News Agency.* http://www.china.org.cn/china/2012-06/30/content_25773810.htm. (accessed 25 January 2018).

Deng, S. (2018) '1,700 Arrested in Shoddy Farm Products Crackdown', *Xinhua News Agency*.

Dercon, S. (2002) 'Income Risk, Coping Strategies, and Safety Nets', *The World Bank Research Observer* 17(2): 141–66.

Dercon, S. and L. Christiaensen (2011) 'Consumption Risk, Technology Adoption and Poverty Traps: Evidence from Ethiopia', *Journal of Development Economics* 96(2): 159–73.

Dethier, J. and A. Effenberger (2012) 'Agriculture and Development: A Brief Review of the Literature', *Economic Systems* 36(2): 175–205.

DFID (1999) 'DFID Sustainable Livelihoods Guidance Sheets', *Department of International Development. Emergency Nutrition Network (ENN)*. https://www.ennonline.net/dfidsustainableliving (accessed 22 March 2018).

Diagne, A., M. Zeller, and M. Sharma (2000) 'Empirical Measurements of Households' Access to Credit and Credit Constraints in Developing Countries: Methodological Issues and Evidence'. International Food Policy Research Institute, Washington, DC.

Doutriaux, S., C. Geisler, and G. Shively (2008) 'Competing for Coffee Space: Development-Induced Displacement in the Central Highlands of Vietnam', *Rural Sociology* 73(4): 528–54.

Duflo, E., M. Kremer, and J. Robinson (2011) 'Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya', *American Economic Review* 101(6): 2350–90.

Ebenstein, A. (2010) 'The Consequences of Industrialization: Evidence from Water Pollution and Digestive Cancers in China', *Review of Economics and Statistics* 94(1): 186–201.

Emerick, K., A. De Janvry, E. Sadoulet, and M.H. Dar (2016) 'Technological Innovations, Downside Risk, and the Modernization of Agriculture', *American Economic Review* 106(6): 1537–61.

Evenson, R.E. and D. Gollin (2003) 'Assessing the Impact of the Green Revolution, 1960 to 2000', *Science* 300(5620): 758–62.

Fagerland, M.W., S. Lydersen, and P. Laake (2013) 'The McNemar Test for Binary Matched-Pairs Data: Mid-p and Asymptotic Are Better than Exact Conditional', *BMC Medical Research Methodology* 13: 91.

FAO (1999) 'Report of the Third Tropical Asian Maize Network (TAMNET) Meeting', *Hanoi, Vietnam 27-29 October 1998*.

FAO (2012) 'The State of Food and Agriculture: Investing in Agriculture for a Better Future'. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

FAOSTAT (2020) 'Rice Export and Import Data'. http://www.fao.org/faostat/en/#data/TP (accessed 10 October 2020).

Fatoux, C., J.-C. Castella, M. Zeiss, and P.H. Manh (2002) 'From Rice Cuitivator to Agroforester within a Decade: The Impact of Doi Moi on Agricultural Diversification in a Mountainous Commune of Cho Moi District, Bae Kan Province, Viet Nam', in J.-C. Castella and D.D. Quang (eds) *Doi Moi in the Mountains: Land Use Changes and Farmers' Livelihood Strategies in Bac Kan Province, Viet Nam*, pp. 73–97. Ha Noi, Vietnam: The Agricultural Publishing House.

Feder, G., R.E. Just, and D. Zilberman (1985) 'Adoption of Agricultural Innovations in Developing Countries : A Survey', *Economic Development and Cultural Change* 33(2): 255–98.

Field, A. (2018) *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). Sage Publications Ltd.

Fisher, M. and E.R. Carr (2015) 'The Influence of Gendered Roles and Responsibilities on the Adoption of Technologies That Mitigate Drought Risk: The Case of Drought-Tolerant Maize Seed in Eastern Uganda', *Global Environmental Change* 35: 82–92.

Fisher, R.A. (1935) 'The Logic of Inductive Inference', *Journal of the Royal Statistical Society* 98: 39–82.

Fortin, N., T. Lemieux, and S. Firpo (2011) *Decomposition Methods in Economics*, *Handbook of Labor Economics* (Vol. 4). Elsevier Inc.

Foster, A.D. and M.R. Rosenzweig (1995) 'Learning by Doing and Learning from Others : Human Capital and Technical Change in Agriculture', *Journal of Political Economy* 103(6): 1176–209.

Fuglie, K., M. Gautam, A. Goyal, and W.F. Maloney (2020) *Harvesting Prosperity: Technology and Productivity Growth in Agriculture*. The World Bank, Washington, DC.

Gebremedhin, B., M. Jaleta, and D. Hoekstra (2009) 'Smallholders, Institutional Services, and Commercial Transformation in Ethiopia', *Agricultural Economics* 40(SUPPL. 1): 773–87.

Glewwe, P. (2004) 'An Overview of Economic Growth and Household Welfare in Vietnam in the 1990s', in P. Glewwe et al. (eds) *Economic Growth, Poverty, and Household Welfare in Vietnam*, pp. 1–26. The World Bank, Washington DC.

Glewwe, P., M. Gragnolati, H. Zaman, and P. Glewwe (2002) 'Who Gained from Vietnam's Boom in the 1990s?', *Economic Development and Cultural Change* 50(4): 773–92.

Grootaert, C. (1998) 'Social Capital: The Missing Link?' Social Capital Initiative, The World Bank, Washington, DC.

GSO (2006) *Statistical Yearbook of Vietnam 2006*. General Statistics Office Of Vietnam.

GSO (2007) *Statistical Yearbook of Vietnam 2007*. General Statistics Office Of Vietnam.

GSO (2009) *The 2009 Vietnam Population and Housing Census: Completed Results*. General Statistics Office of Vietnam.

GSO (2011) 'Consumer Price Index', *General Statistics Office Of Vietnam*. https://www.gso.gov.vn/en/homepage/ (accessed 16 November 2011).

GSO (2020) 'Statistical Censuses and Surveys', *General Statistics Office Of Vietnam*. https://www.gso.gov.vn/en/homepage/ (accessed 17 August 2020).

Hamilton, L.C. (n.d.) 'Resistant Normality Check and Outlier Identification'. Department of Sociology, University of New Hampshire.

Hardaker, B.J., G. Lien, J.R. Anderson, and R.B.M. Huirne (2015) *Coping with Risk in Agriculture: Applied Decision Analysis* (Third Edition.). CAB International.

Hazell, P.B.R. (2009) 'The Asian Green Revolution'. International Food Policy Research Institute, Washington, DC.

Henin, B. (2002) 'Agrarian Change in Vietnam's Northern Upland Region', *Journal of Contemporary Asia* 32(1): 3–28.

Henry, C., M. Sharma, C. Lapenu, and M. Zeller (2003) 'Microfinance Poverty Assessment Tool', *Technical Tools Series No. 5*. Washington, DC: The World Bank and Consultative Group to Assist the Poor.

Hoang, Q.D., T.B. Dufhues, and G. Buchenrieder (2016) 'Individual Social Capital and Access to Rural Services in Northern Vietnam', *International Journal of Social Economics* 43(4): 363–81.

Holden, S.T. and J. Quiggin (2017) 'Climate Risk and State-Contingent Technology Adoption: Shocks, Drought Tolerance and Preferences', *European Review of Agricultural Economics* 44(2): 285–308.

Holt, C.A. and S.K. Laury (2002) 'Risk Aversion and Incentive Effects', *American Economic Review* 92(5): 1644–55.

Hossain, M. and V.P. Singh (2000) 'Fertilizer Use in Asian Agriculture: Implications for Sustaining Food Security and the Environment', *Nutrient Cycling in Agroecosystems* 57(2): 155–69.

Isik, M. and M. Khanna (2003) 'Stochastic Technology, Risk Preferences, and Adoption of Site-Specific Technologies', *American Journal of Agricultural Economics* 85(2): 305–17.

Ivanic, M. and W. Martin (2018) 'Sectoral Productivity Growth and Poverty Reduction: National and Global Impacts', *World Development* 109: 429–39.

Jann, B. (2008) 'A Stata Implementation of the Blinder-Oaxaca Decomposition', *The Stata Journal* 8(4): 453–79.

JICA (2013) 'Agricultural Transformation & Food Security 2040, ASEAN Region with a Focus on Vietnam, Indonesia, and Philippines, Vietnam Country Report'. Japan International Cooperation Agency (JICA).

Just, R.E. and D. Zilberman (1983) 'Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture', *Oxford Economic Papers* 35(2): 307–28.

Kaiser, H. (1974) 'An Index of Factorial Simplicity', *Psychometrika* 39(1): 31–6.

Kang, W. and K.S. Imai (2012) 'Pro-Poor Growth, Poverty and Inequality in Rural Vietnam', *Journal of Asian Economics* 23(5): 527–39.

Keil, A., C. Saint-Macary, and M. Zeller (2013) ‘Intensive Commercial Agriculture in Fragile Uplands of Vietnam: How to Harness Its Poverty Reduction Potential While Ensuring Environmental Sustainability?’, *Quarterly Journal of International Agriculture* 52(1): 1–25.

Khonje, M., J. Manda, A.D. Alene, and M. Kassie (2015) ‘Analysis of Adoption and Impacts of Improved Maize Varieties in Eastern Zambia’, *World Development* 66: 695 706-706.

Khor, L.Y., S. Ufer, T. Nielsen, and M. Zeller (2018) ‘Impact of Risk Aversion on Fertiliser Use: Evidence from Vietnam’, *Oxford Development Studies* 46(4): 483–96.

Kilic, T., A. Palacios-López, and M. Goldstein (2015) ‘Caught in a Productivity Trap: A Distributional Perspective on Gender Differences in Malawian Agriculture’, *World Development* 70(March): 416–63.

Kolmogorov, A.N. (1933) ‘Sulla Determinazione Empirica Di Una Legge Di Distribuzione’, *Giornale Dell’ Istituto Italiano Degli Attuari* 4: 83–91.

Kompas, T., T.N. Che, H.T.M. Nguyen, and H.Q. Nguyen (2012) ‘Productivity, Net Returns, and Efficiency: Land and Market Reform in Vietnamese Rice Production’, *Land Economics* 88(3): 478–95.

Kono, Y. and A.T. Rambo (2004) ‘Some Key Issues Relating to Sustainable Agro-Resources Management in the Mountainous Region of Mainland Southeast Asia’, *Southeast Asian Studies* 41(4): 550–65.

Kormawa, P., A. Munyemana, and B. Soule (2003) ‘Fertilizer Market Reforms and Factors Influencing Fertilizer Use by Small-Scale Farmers in Benin’, *Agriculture, Ecosystems & Environment* 100(2): 129–36.

Krishnan, P. and M. Patnam (2014) ‘Neighbors and Extension Agents in Ethiopia: Who Matters More for Technology Adoption?’, *American Journal of Agricultural Economics* 96(1): 308–27.

Kruskal, W.H. and W.A. Wallis (1952) ‘Use of Ranks in One-Criterion Variance Analysis’, *Journal of the American Statistical Association* 47: 583–621.

Kruskal, W.H. and W.A. Wallis (1953) ‘Errata: Use of Ranks in One-Criterion Variance Analysis’, *Journal of the American Statistical Association* 48: 907–11.

Kyeyune, V. and S. Turner (2016) ‘Yielding to High Yields? Critiquing Food Security Definitions and Policy Implications for Ethnic Minority Livelihoods in Upland Vietnam’, *Geoforum* 71: 33–43.

Lambrecht, I., B. Vanlauwe, R. Merckx, and M. Maertens (2014) ‘Understanding the Process of Agricultural Technology Adoption: Mineral Fertilizer in Eastern DR Congo’, *World Development* 59: 132–46.

Lançon, F., D. Sautier, and T.A. Dao (2014) ‘Vietnam: Rural Connectivity and Agriculture Logistics in Domestic Market Supply Chains’. The World Bank.

Leisz, S.J., N.T.T. Ha, N.T.B. Yen, N.T. Lam, and T.D. Vien (2005) ‘Developing a Methodology for Identifying, Mapping and Potentially Monitoring the Distribution of General Farming System Types in Vietnam’s Northern Mountain Region’, *Agricultural Systems* 85(3 SPEC. ISS.): 340–63.

Lippe, M. et al. (2011) ‘Building on Qualitative Datasets and Participatory Processes to Simulate Land Use Change in a Mountain Watershed of Northwest Vietnam’, *Environmental Modelling and Software* 26(12): 1454–66.

Liu, X. et al. (2013) ‘Enhanced Nitrogen Deposition over China’, *Nature* 494(7438): 459–62.

Liverpool-Tasie, S., B. Olaniyan, S. Salau, and J. Sackey (2010) ‘A Review of Fertilizer Policy Issues in Nigeria’. Nigeria Strategy Support Program, International Food Policy Research Institute (IFPRI).

Luan, D.X. and S. Bauer (2016) ‘Does Credit Access Affect Household Income Homogeneously across Different Groups of Credit Recipients? Evidence from Rural Vietnam’, *Journal of Rural Studies* 47: 186–203.

Luan, D.X. and A.J. Kingsbury (2019) ‘Thinking beyond Collateral in Value Chain Lending: Access to Bank Credit for Smallholder Vietnamese Bamboo and Cinnamon Farmers’, *International Food and Agribusiness Management Review* 22(4): 535–55.

Luckmann, J., R. Ihle, U. Kleinwechter, and H. Grethe (2015) ‘Do Vietnamese Upland Farmers Benefit from High World Market Prices for Maize?’, *Agricultural Economics (United Kingdom)* 46: 1–11.

Lunduka, R., M. Fisher, and S. Snapp (2012) ‘Could Farmer Interest in a Diversity of Seed Attributes Explain Adoption Plateaus for Modern Maize Varieties in Malawi?’, *Food Policy* 37(5): 504–10.

Mann, H.B. and D.R. Withney (1947) 'On a Test of Whether One of Two Random Variables Is Stochastically Larger than the Other', *Annals of Mathematical Statistics* 18: 50–60.
Maredia, M. et al. (2017) 'Varietal Release and Adoption Data for South, Southeast, and East Asia: SIAC Project (2013-2016)'. https://www.asti.cgiar.org/siac (accessed 15 January 2020).
Marenya, P.P. and C.B. Barrett (2009a) 'Soil Quality and Fertilizer Use Rates among Smallholder Farmers in Western Kenya', *Agricultural Economics* 40(5): 561–72.
Marenya, P.P. and C.B. Barrett (2009b) 'State-Conditional Fertilizer Yield Response on Western Kenyan Farms', *American Journal of Agricultural Economics* 91(4): 991–1006.
Marenya, P.P., M.B. Kassie, M.D. Jaleta, and D.B. Rahut (2017) 'Maize Market Participation among Female- and Male-Headed Households in Ethiopia', *Journal of Development Studies* 53(4): 481–94.
Matuschke, I. and M. Qaim (2009) 'The Impact of Social Networks on Hybrid Seed Adoption in India', *Agricultural Economics* 40(5): 493–505.
Michaud, J., S. Turner, and Y. Roche (2002) 'Mapping Ethnic Diversity in Highland Northern Vietnam', *Geo Journal* 57: 281–99.
Minot, N., B. Baulch, and M. Epprecht (2003) 'Poverty and Inequality in Vietnam: Spatial Patterns and Geographic Determinants'. International Food and Policy Research Institute and Institute of Development Studies.
Minot, N., M. Epprecht, T.T.T. Anh, and L.Q. Trung (2006) 'Income Diversification and Poverty in the Northern Uplands of Vietnam'. International Food Policy Research Institute, Washington, DC .
Minten, B., B. Koru, and D. Stifel (2013) 'The Last Mile(s) in Modern Input Distribution: Pricing, Profitability, and Adoption', *Agricultural Economics* 44(6): 629–46.
Mugisha, J. and G. Diiro (2010) 'Explaining the Adoption of Improved Maize Varieties and Its Effects on Yields among Smallholder Maize Farmers in Eastern and Central Uganda', *Middle-East Journal of Scientific Research* 5(1): 6–13.
Neumark, D. (1988) 'Employers' Discriminatory Behavior and the Estimation of Wage Discrimination', *The Journal of Human Resources* 23(3): 279–95.
Ngoc, N.T.H. and S. Yokoyama (2019) 'Driving Forces for Livelihood Structure Changes in Vietnam's Northwestern Mountainous Region: A Case Study on Yen Chau District, Son La Province', *Tropics* 27(4): 81–97.
Nguyen, C.V., T.Q. Tran, and H. Van Vu (2017) 'Ethnic Minorities in Northern Mountains of Vietnam: Employment, Poverty and Income', *Social Indicators Research* 134(1): 93–115.
Nguyen, L. (2019) 'Land Rights and Technology Adoption: Improved Rice Varieties in Vietnam', *Journal of Development Studies* 00(00): 1–19.
Nguyen, T.H. (2017) 'An Overview of Agricultural Pollution in Vietnam: The Crops Sector'. Prepared for The World Bank, Washington, DC.
Nguyen, T.T. (2012) 'Land Reform and Farm Production in the Northern Uplands of Vietnam', *Asian Economic Journal* 26(1): 43–61.
Nguyen, T.T., S. Bauer, and U. Grote (2016) 'Does Land Tenure Security Promote Manure Use by Farm Households in Vietnam?', *Sustainability (Switzerland)* 8(2): 1–19.
Nguyen, V.C. (2011) 'Can Vietnam Achieve the Millennium Development Goal on Poverty Reduction in High Inflation and Economic Stagnation?', *Developing Economies* 49(3): 297–320.
Nielsen, T., A. Keil, and M. Zeller (2013) 'Assessing Farmers' Risk Preferences and Their Determinants in a Marginal Upland Area of Vietnam: A Comparison of Multiple Elicitation Techniques', *Agricultural Economics (United Kingdom)* 44(3): 255–73.
Nkana, N. (2016, June) 'ZABS Seizes Fake Fertiliser', *Zambia Daily Mail*. https://www.daily-mail.co.zm/zabs-seizes-fake-fertiliser/ (accessed 25 January 2018).
Oaxaca, R.L. (1973) 'Male-Female Wage Differentials in Urban Labor Markets', *International Economic Review* 14(3): 693–709.
Oaxaca, R.L. and M.R. Ransom (1994) 'On Discrimination and the Decomposition of Wage Differentials', *Journal of Econometrics* 61(1): 5–21.
Oseni, G., P. Corral, M. Goldstein, and P. Winters (2015) 'Explaining Gender Differentials in Agricultural Production in Nigeria', *Agricultural Economics (United Kingdom)* 46(3): 285–310.

Pearson, K. (1900) 'On the Criterion That a given System of Deviations from the Probable in the Case of a Correlatedsystem of Variables Is Such That It Can Be Reasonably Supposed to Have Arisen from Random Sampling', *Philosophical Magazine* Series 5(50): 157–75.

Pembury Smith, M.Q.R. and G.D. Ruxton (2020) 'Effective Use of the McNemar Test', *Behavioral Ecology and Sociobiology* 74(11).

Phan, D. (2012) 'Migration and Credit Constraints: Theory and Evidence from Vietnam', *Review of Development Economics* 16(1): 31–44.

Phien, C. (2013, September) 'Counterfeit Fertilizer Flooding Local Market', *Sai Gon Giai Phong Newspaper*. http://sggpnews.org.vn/business/counterfeit-fertilizer-flooding-local-market-34661.html (accessed 25 January 2018).

Pingali, P.L. (2014) 'Green Revolution: Impacts, Limits, and the Path Ahead', in W. Falcon (ed.) *Frontiers in Food Policy*, pp. 89–106. Stanford, CA: Stanford University Press.

Pingali, P.L. and V.-T. Xuan (1992) 'Vietnam: Decollectivization and Rice Productivity Growth', *Economic Development and Cultural Change* 40(4): 697–718.

PovcalNet (2020) 'PovcalNet Stata Command Estimating Global Poverty in Stata', *The World Bank*. https://worldbank.github.io/povcalnet/ (accessed 23 March 2020).

Quisumbing, A.R. and N. Kumar (2011) 'Does Social Capital Build Women's Assets? The Long-Term Impacts of Group-Based and Individual Dissemination of Agricultural Technology in Bangladesh', *Journal of Development Effectiveness* 3(2): 220–42.

Robison, L.J. and P.J. Barry (1987) *The Competitive Firm's Response to Risk*. New York: Macmillan Publishing Company.

Rogers, E.M. (1962) *Diffusion of Innovations, Glenoe: Free Press*.

Roosen, J. and D.A. Hennessy (2003) 'Tests for the Role of Risk Aversion on Input Use', *American Journal of Agricultural Economics* 85(1): 30–43.

Rosenzweig, M.R. and H.P. Binswanger (1993) 'Wealth , Weather Risk and the Composition and Profitability of Agricultural Investments', *The Economic Journal* 103(416): 56–78.

Rusinamhodzi, L., S. Dahlin, and M. Corbeels (2016) 'Living within Their Means: Reallocation of Farm Resources Can Help Smallholder Farmers Improve Crop Yields and Soil Fertility', *Agriculture, Ecosystems and Environment* 216: 125–36.

Sadoulet, D., J.-C. Castella, V.H. Nam, and D.D. Quang (2002) 'A Short History of Land Use Changes and Farming System Differentiation in Xual Hoa Commune, Bac Kan Province, Viet Nam', in J.-C. Castella and D.D. Quang (eds) *Doi Moi in the Mountains Land Use Changes and Farmers' Livelihood Strategies in Bac Kan Province, Viet Nam*, pp. 21–46. Ha Noi, Vietnam: The Agricultural Publishing House.

Saenger, C., M. Torero, and M. Qaim (2014) 'Impact of Third-Party Contract Enforcement in Agricultural Markets – A Field Experiment in Vietnam', *American Journal of Agricultural Economics* 96(4): 1220–38.

Saint-Macary, C. (2014) *Microeconomic Impacts of Institutional Change in Vietnam's Northern Uplands: Empirical Studies on Social Capital, Land and Credit Institutions*. Frankfurt am Main: Peter Lang GmbH, Internationaler Verlag der Wissenschaften.

Schreinemachers, P., H.L. Fröhlich, G. Clemens, and K. Stahr (2013) 'From Challenges to Sustainable Solutions for Upland Agriculture in Southeast Asia', in Fröhlich Holger L. et al. (eds) *Sustainable Land Use and Rural Development in Southeast Asia: Innovations and Policies for Mountainous Areas*, pp. 3–27. Springer Environmental Science and Engineering.

Schultz, T.W. (1964) *Transforming Traditional Agriculture*. New Haven: Yale University Press.

Scoones, I. (1998) 'Sustainable Rural Livelihoods: A Framework for Analysis'. Institute of Development Studies, Brighton, United Kingdom.

Shaddick, P. (2007) 'Compound Fertilizers in South East Asia', *International Fertilizer Industry Association Crossroads Asia-Pacific Conference*. Bali, Indonesia.

Shapiro, S.S. and M.B. Wilk (1965) 'An Analysis of Variance Test for Normality (Complete Samples)', *Biometrika* 52: 591–611.

Sheahan, M., J. Ariga, and T.S. Jayne (2016) ‘Modeling the Effects of Input Market Reforms on Fertiliser Demand and Maize Production: A Case Study from Kenya’, *Journal of Agricultural Economics* 67(2): 420–47.

Shorrocks, A.F. (1982) ‘Inequality Decomposition by Factor Components’, *Econometrica* 50: 193–211.

Siegel, P.B. and J. Alwang (1999) ‘An Asset-Based Approach to Social Risk Management: A Conceptual Framework’. The World Bank, Washington, DC.

Sikor, T. and P.T.T. Vi (2005) ‘The Dynamics of Commoditization in a Vietnamese Uplands Village, 1980-2000’, *Journal of Agrarian Change* 5(3): 405–28.

Simtowe, F. et al. (2011) ‘Determinants of Agricultural Technology Adoption: The Case of Improved Pigeonpea Varieties in Tanzania’, *Quarterly Journal of International Agriculture* 50(4): 325–45.

Simtowe, F., M. Zeller, and A. Diagne (2009) ‘The Impact of Credit Constraints on the Adoption of Hybrid Maize in Malawi’, *Review of Agricultural and Environmental Studies* 90(1): 5–22.

Sinyolo, S., M. Mudhara, and E. Wale (2016) ‘The Impact of Social Grants on the Propensity and Level of Use of Inorganic Fertiliser among Smallholders in Kwazulu-Natal, South Africa’, *Agrekon* 55(4): 436–57.

Smirnov, N. V. (1933) ‘Estimate of Deviation between Empirical Distribution Functions in Two Independent Samples’, *Bulletin Moscow University* 2: 3–16.

Smith, R.E. (2008) ‘Cattle’s Effect on Land and Labour Productivity: Evidence from Zambia’, *Journal of International Development* 20: 905–19.

Staal, S.J., J. Raneri, D.P. Nguyen, and J. Hammond (2014) ‘A Situational Analysis of Agricultural Production and Marketing, and Natural Resources Management Systems in Vietnam’. International Livestock Research Institute (ILRI).

Stampini, M. and B. Davis (2009) ‘Does Nonagricultural Labor Relax Farmers’ Credit Constraints? Evidence from Longitudinal Data for Vietnam’, *Agricultural Economics* 40(2): 177–88.

STATA (2017) *Stata Base Reference Manual* (Vol. Release 15). College Station, Texas: StataCorp LLC.

Sunding, D. and D. Zilberman (2001) ‘The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector’, in B.L. Gardner and G.C. Rausser (eds) *Handbook of Agricultural Economics: Agricultural Production*, pp. 207–61 (Vol. 1, Part A). North-Holland.

Takeshima, H. and E. Nkonya (2014) ‘Government Fertilizer Subsidy and Commercial Sector Fertilizer Demand: Evidence from the Federal Market Stabilization Program (FMSP) in Nigeria’, *Food Policy* 47: 1–12.

Teshome, A., J. de Graaff, and A. Kessler (2016) ‘Investments in Land Management in the North-Western Highlands of Ethiopia: The Role of Social Capital’, *Land Use Policy* 57: 215–28.

Thanh, D. et al. (2004) ‘Maize in Vietnam: Production Systems, Constraints, and Research Priorities’. Mexico, D.F.: CIMMYT.

Thanh, H.X. and K. Neefjes (2005) ‘Economic Integration and Maize-Based Livelihoods of Poor Vietnamese’. Vietnam Institute Of Economics, Hanoi, Vietnam.

The World Bank (2012) ‘Well Begun, Not Yet Done: Vietnam’s Remarkable Progress on Poverty Reduction and the Emerging Challenges’. The World Bank in Vietnam, Hanoi, Vietnam.

The World Bank (2014) ‘PPP Conversion Factor, Private Consumption (LCU per International $)’. https://data.worldbank.org/indicator/PA.NUS.PRVT.PP. (accessed 25 January 2018).

The World Bank (2020) ‘World Bank Open Data, PPP Conversion Factor, Private Consumption (LCU per International $)’. https://data.worldbank.org/indicator/PA.NUS.PRVT.PP?end=2019&locations=VN&start=1990&view=chart (accessed 24 March 2020).

Thulstrup, A.W. (2015) ‘Livelihood Resilience and Adaptive Capacity: Tracing Changes in Household Access to Capital in Central Vietnam’, *World Development* 74: 352–62.

To-The, N. and T. Nguyen-Anh (2021) ‘Impact of Government Intervention to Maize Efficiency at Farmer’s Level across Time: A Robust Evidence in Northern Vietnam’, *Environment, Development and Sustainability* 23: 2038–61.

Tran, D.V. (2003) ‘Culture, Environment, and Farming Systems in Vietnam’s Northern Mountain Region’, *Southeast Asian Studies* 41(2): 180–205.

Van Tran, T.K. et al. (2019) 'Gender Gap in Rice Productivity: Evidence from Vietnam', *International Journal of Social Economics* 46(2): 241–51.

Tuan, V.D. et al. (2014) 'Mitigation Potential of Soil Conservation in Maize Cropping on Steep Slopes', *Field Crops Research* 156: 91–102.

Tuyen, T.Q. (2015) 'Socio-Economic Determinants of Household Income among Ethnic Minorities in the North-West Mountains, Vietnam', *Croatian Economic Survey* 17(1): 139–59.

Tuyen, T.Q. (2016) 'Income Sources and Inequality among Ethnic Minorities in the Northwest Region, Vietnam', *Environment, Development and Sustainability* 18(4): 1239–54.

Ufer, S. (2010) 'Coping and Adaptation Strategies of Rural Households in Response to Rice and Maize Price Variability in Northern Vietnam'. University of Hohenheim.

USDA-ERS (2019) 'International Agricultural Productivity', *US Department of Agriculture Economic Research Service*.

Van De Walle, D. and D. Gunewardena (2001) 'Sources of Ethnic Inequality in Viet Nam', *Journal of Development Economics* 65(1): 177–207.

Wezel, A., A. Luibrand, and L.Q. Thanh (2002a) 'Temporal Changes of Resource Use, Soil Fertility and Economic Situation in Upland Northwest Vietnam', *Land Degradation & Development* 13: 33–44.

Wezel, A., N. Steinmüller, and J.R. Friederichsen (2002b) 'Slope Position Effects on Soil Fertility and Crop Productivity and Implications for Soil Conservation in Upland Northwest Vietnam', *Agriculture Ecosystems & Environment* 91(1–3): 113–26.

Wilcoxon, F. (1945) 'Individual Comparisons by Ranking Methods', *Biometrics* 1: 80–3.

Wooldridge, J.M. (2012) *Introductory Econometrics: A Modern Approach* (Vol. 5th Edition). South-Western, Cengage Learning.

Wubeneh, N.G. and J.H. Sanders (2006) 'Farm-Level Adoption of Sorghum Technologies in Tigray, Ethiopia', *Agricultural Systems* 91(1–2): 122–34.

Yadav, S.N., W. Peterson, and K.W. Easter (1997) 'Do Farmers Overuse Nitrogen Fertilizer to the Detriment of the Environment?', *Environmental and Resource Economics* 9(3): 323–40.

Yagura, K. (2009) 'Safety Net Perception and Its Effects on Household Investment in Developing Countries: Chemical Fertilizer Input by Cambodian Farmers', *Oxford Development Studies* 37(4): 363–95.

Yamano, T. and Y. Kijima (2010) 'The Associations of Soil Fertility and Market Access with Household Income: Evidence from Rural Uganda', *Food Policy* 35(1): 51–9.

Yen, B.T., S.M. Visser, C.T. Hoanh, and L. Stroosnijder (2013) 'Constraints on Agricultural Production in the Northern Uplands of Vietnam', *Mountain Research and Development* 33(4): 404–15.

Zahur, A. (2010, February) 'Spurious Fertilizers: A Threat to Agriculture', *The Daily Star*. http://www.thedailystar.net/news-detail-125044 (accessed 25 January 2018).

Zeller, M., G. Schrieder, J. Von Braun, and F. Heidhues (1997) 'Rural Finance for Food Security for the Poor: Implications for Research and Policy'. International Food Policy Research Institute, Washington, DC.

Zeller, M., M. Sharma, C. Henry, and C. Lapenu (2006) 'An Operational Method for Assessing the Poverty Outreach Performance of Development Policies and Projects: Results of Case Studies in Africa, Asia, and Latin America', *World Development* 34(3): 446–64.

Zerfu, D. and D.F. Larson (2010) 'Incomplete Markets and Fertilizer Use: Evidence from Ethiopia'. The World Bank.

Zezza, A. et al. (2011) 'Rural Household Access to Assets and Agrarian Institutions: A Cross Country Comparison', *The European Journal of Development Research* 23(4, September): 569–97.

Zhao, P. et al. (2016) 'Training and Organization Programs Increases Maize Yield and Nitrogen-Use Efficiency in Smallholder Agriculture in China', *Agronomy Journal* 108(5): 1944–50.

Zimmerman, F.J. and M.R. Carter (2003) 'Asset Smoothing, Consumption Smoothing and the Reproduction of Inequality under Risk and Subsistence Constraints', *Journal of Development Economics* 71(2): 233–60.

Appendices

Appendix A: Selection model

Table A-1: Results of the selection model (Tobit regression)

VARIABLES	(T.1) 2007	(T.2) 2008	(T.3) 2009	(T.4) 2010
Farm area, value adjusted [million VND m²]	-0.0450 (0.2049)	-0.2392 (0.2309)	-0.4378 (0.2728)	-0.3696 (0.2405)
Log land value all farm land [VND/m²]	-1.2805 (2.6976)	1.0077 (3.0305)	-0.5016 (4.8681)	1.8912 (4.6456)
Log land value upland [VND/m²]	3.1786* (1.8044)	2.6837 (3.3091)	2.0659 (3.7575)	2.8835 (2.8775)
[%] Upland in farm area	0.3920*** (0.0907)	0.3918** (0.1712)	0.3838*** (0.1074)	0.3029*** (0.1062)
Log distance upland [walking minutes]	2.3400* (1.3871)	4.0321** (1.9172)	1.1117 (1.4591)	3.7192** (1.8369)
Paddy land in farm area [%]	-0.3196** (0.1396)	-0.2259 (0.2168)	0.1061 (0.1505)	-0.2285* (0.1334)
Share LURC in farm area [%]	-0.0088 (0.0260)	0.0267 (0.0566)	-0.0257 (0.0494)	0.0543 (0.0346)
Elevation [m]	-0.0016 (0.0074)	-0.0169* (0.0091)	-0.0043 (0.0095)	-0.0082 (0.0071)
Age HH head [years]	-0.2902*** (0.0953)	-0.4948*** (0.1010)	-0.2027 (0.1359)	-0.1570 (0.1191)
Education HH head [years]	-0.0512 (0.3667)	0.2100 (0.3643)	0.5506 (0.3742)	0.2481 (0.2595)
Sex HH head [1=male]	-6.4149 (4.4252)	0.3830 (6.3765)	-6.5712 (6.0314)	-9.8726* (5.3568)
Ethnic group HH head [1=Hmong]	0.3458 (5.8333)	25.3710*** (8.9312)	3.1352 (5.9476)	3.5995 (5.0646)
Ethnic group HH head [1=Kinh]	18.6459*** (5.9086)	18.6358*** (6.1169)	22.7156** (11.3502)	25.5742*** (6.1577)
Dependency ratio [% HH members < 15yrs; > 64yrs]	3.7968 (4.1378)	3.5388 (6.0582)	-0.4588 (6.6331)	-3.2010 (6.6112)
Labour availability [adults > 15yrs/ha]	-0.9907** (0.4181)	-1.1394** (0.4766)	-0.4812* (0.2696)	-0.5745*** (0.2202)
Off-farm income [%]	-0.0482 (0.0678)	-0.0348 (0.0489)	-0.2520*** (0.0676)	-0.2039*** (0.0637)
Log credit limit, deflated [000VND]	0.3977 (2.2309)	-0.9163 (1.9196)	-0.6124 (2.4471)	3.4171* (2.0470)
Log value cattle/buffalo, deflated [000VND]	0.2921 (0.3989)	0.5853 (0.6445)	0.6719 (0.4823)	0.5463 (0.5077)

Table A-1: Results of the selection model (Tobit regression) continued ………

VARIABLES	(T.1) 2007	(T.2) 2008	(T.3) 2009	(T.4) 2010
HH with good extension access in village [%]	3.9567 (7.0435)	-0.3244 (6.7490)	9.6051* (5.5643)	4.4226 (5.5277)
Paved road distance [walking min]	0.2194*** (0.0716)	0.1267 (0.0866)	0.1170* (0.0608)	0.0734* (0.0386)
HH is poor [1=poor]	3.2953 (2.6870)	-4.8452 (4.7490)	1.0679 (2.8793)	10.2426*** (3.7205)
Constant	42.5215 (30.5999)	44.5195* (26.8992)	49.5336 (36.6178)	-9.9984 (26.1298)
Observations	294	291	287	287
Prob > F	0.0000	0.0000	0.0000	0.0000
Pseudo_R2	0.0838	0.0595	0.0561	0.0851
Left censored [%]	2.38	4.12	3.14	3.48
Right censored [%]	9.52	8.59	6.97	5.92

Robust standard errors in parentheses, clustered at village level: *** p<0.01, ** p<0.05, * p<0.1

Source: Own data

Appendix B: Questionnaires

The questionnaires this doctoral thesis relies on can be found under:

http://opus.uni-hohenheim.de/volltexte/2022/2020