Vulnerability, Adaptive Strategies, and Household Welfare in Rural Southeast Asia

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Zusammenfassung

Südostasiatische Länder haben in den letzten Jahrzehnten bemerkenswertes Wirtschaftswachstum erlebt. Dennoch sind die lokalen Haushalte immer noch anfällig gegenüber Naturkatastrophen, da sie sich in einer Region mit einem hohen Risiko für Katastrophen befinden. Die Vulnerabilität von Haushalten ist in ländlichen Gebieten besonders ausgeprägt, da ihre Lebensgrundlagen stark von der Landwirtschaft abhängen und die Einkommensungleichheit dort relativ groß ist. Interventionen, die darauf abzielen, die Anpassungsfähigkeit der Haushalte zu verbessern und deren Resilienz zu stärken, müssen auf praktischer Evidenz beruhen. Daher verwendet diese Dissertation einen umfassenden Datensatz, der in ländlichen Gebieten von Kambodscha, Laos, Thailand und Vietnam gesammelt wurde, um i) die Anfälligkeit von Haushalten gegenüber Schocks und Unterernährung und ii) die Rolle verschiedener adaptiver Lebensunterhaltsstrategien bei der Minderung von Schocks und Verbesserung des Wohlergehens der Haushalte zu untersuchen und zu vergleichen. Die Dissertation besteht aus vier Forschungsarbeiten, die in Kapitel 2 bis Kapitel 5 vorgestellt werden.

Das erste Papier mit dem Titel „Gesundheitsschocks, Haushaltskonsum und Diversifizierung der Lebensgrundlagen: Eine vergleichende Evidenz aus Paneldaten in Thailand und Vietnam“ zielt darauf ab, die Auswirkungen von kovariaten und idiosynkratischen Schocks auf den Haushaltskonsum und die Wirksamkeit von Strategien zur Diversifizierung der Lebensgrundlagen als Reaktion auf diese Schocks zu analysieren. Die Ergebnisse zeigen, dass (i) ländliche Haushalte in beiden Ländern in der Lage sind, ihren Pro-Kopf-Konsum angesichts idiosynkratischer Schocks, aber nicht kovariater Schocks aufrechtzuerhalten; (ii) dass Arbeitsdiversifizierung in Thailand und Landdiversifizierung in Vietnam als Ex-post-Bewältigungsstrategien gegen kovariate Schocks eingesetzt werden, sich aber nicht signifikant schockmindernd auswirken; (iii) und dass Landdiversifizierung in Thailand und

Arbeitsdiversifizierung in Vietnam den Pro-Kopf-Konsum erhöhen können, wenn Haushalte mit kovariaten Schocks konfrontiert werden. Diese Ergebnisse deuten darauf hin, dass sich erleichterter Zugang zu Krediten, verbesserte landwirtschaftliche Mechanisierung und erhöhte Straßenqualität in Thailand sowie die Entwicklung lokaler ländlicher Sektoren außerhalb der Landwirtschaft in Vietnam positiv auf die Bewältigung von kovariaten Schocks durch ländliche Haushalte auswirken würden.

Das zweite Papier befasst sich mit „Gesundheitsschocks, Haushaltskonsum und Überschuldung: Spielt der Zugang zu Finanz- und Versicherungsmärkten eine Rolle?“ Es befasst sich mit den Auswirkungen von Gesundheitsschocks – definiert als schwere Krankheitsereignisse – auf den Konsum und die Verschuldung ländlicher Haushalte und untersucht die Rolle der Kredit- und Krankenversicherung zur Milderung der Folgen dieser negativen Ereignisse. Die Resultate zeigen, dass ländliche Haushalte nicht in der Lage sind, den Konsum außerhalb der Gesundheitsversorgung und den Gesamtkonsum zu versichern. Gesundheitsschocks treiben Haushalte erheblich in die Überschuldung aufgrund (i) reduzierten Einkommens aus geringerer Erwerbsfähigkeit und (ii) erhöhter informeller Kreditaufnahme, um den Konsum zu glätten. Es wird empfohlen, Barrieren zum Zugang zu Krankenversicherungen und formellen Krediten zu beseitigen, da dies dazu beiträgt, den Konsumrückgang zu verringern. Zudem schützt eine Krankenversicherung die Haushalte vor einer Überschuldung bei schweren Erkrankungen.

Das dritte Papier befasst sich mit „Schocks, landwirtschaftlicher Produktivität und Abbau natürlicher Ressourcen in Südostasien“. Es verwendet Umfragedaten aus vier südostasiatischen Ländern, darunter Kambodscha, Laos, Thailand und Vietnam, um die Auswirkungen von Schocks und landwirtschaftlicher Produktivität auf die Entnahme natürlicher Ressourcen durch ländliche Haushalte zu untersuchen. Die Ergebnisse zeigen, dass Wetter- und Marktschocks Haushalte dazu zwingen, mehr natürliche Ressourcen abzubauen. Eine gesteigerte

landwirtschaftliche Produktivität hält jedoch vom Abbau natürlicher Ressourcen ab. Darüber hinaus sind geringe Bildung und eingeschränkter Zugang zu Elektrizität positiv mit der Gewinnung natürlicher Ressourcen assoziiert. Diese Ergebnisse legen nahe, dass Maßnahmen zur Steigerung der landwirtschaftlichen Produktivität priorisiert werden sollten und den Landwirt:innen mehr Hilfe und Unterstützung zur Abmilderung der schwerwiegenden Auswirkungen von Wetter- und Marktschocks bereitgestellt werden sollten. Darüber hinaus sollten die Beschleunigung der Mechanisierung landwirtschaftlicher Betriebe, die Defragmentierung des Landes, die ländliche Elektrifizierung, die Unterstützung der Entwicklung von Kommunikationssystemen und lokalen Märkten sowie die Förderung der ländlichen Bildung gefördert werden.

Das vierte Papier befasst sich mit „Überweisungen, sanitäre Einrichtungen und Unterernährung von Kindern: Evidenz aus dem ländlichen Südostasien“ Dieser Aufsatz untersucht die Auswirkungen von Rücküberweisungen auf den Besitz einer Toilette mit Spülung und die Auswirkungen auf die Unterernährung von Kindern im ländlichen Thailand und Vietnam. Die Ergebnisse zeigen, dass Rücküberweisungen die Installation einer Toilette mit Spülung erleichtern und Kinder aus Haushalten ohne Toilette mit Spülung stärker unter Untergewicht und Wachstumsverzögerung leiden. Darüber hinaus sind die Auswirkungen einer Toilettenspülung auf die Gesundheit verschiedener Kindergruppen heterogen. Jüngere, weibliche Kinder und Kinder aus armen Haushalten profitieren deutlich stärker von einer Toilette mit Wasserspülung. Es wird daher empfohlen, ländliche Haushalte bei der Einrichtung von Toiletten mit Wasserspülung zu unterstützen. Darüber hinaus könnte die Förderung ländlicher Bildung und öffentlicher Wasserversorgung die Unterernährung von Kindern in ländlichen Haushalten deutlich reduzieren.

Schlüsselwörter: Südostasien, Vulnerabilität, Lebensunterhaltsstrategien, Anpassungsfähigkeit

Summary

Southeast Asian countries have experienced remarkable economic growth rates in recent decades. However, their households are still vulnerable to natural disasters as they are located in one of the most disaster-prone regions of the world. The degree of vulnerability is even more pronounced in rural areas where livelihoods mainly rely on agriculture and where income inequality is relatively high. Interventions that target at improving household adaptive capacity and enhancing resilience must be based on practical evidence. Thus, this dissertation employs a rich dataset collected in rural areas of Cambodia, Laos, Thailand, and Vietnam to investigate and compare i) the degree of household vulnerability to shocks and malnutrition, and ii) the role of various adaptive livelihood strategies in mitigating shock impacts and improving household welfare. The thesis consists of four research papers that are presented in Chapter 2 to Chapter 5.

The first paper on "Health shocks, household consumption, and livelihood diversification: A comparative evidence from panel data in Thailand and Vietnam" aims to analyse the impact of covariate and idiosyncratic shocks on household consumption and the effectiveness of livelihood diversification strategies in response to these shocks. The results illustrate that (i) rural households in both countries are able to maintain per capita consumption in the face of idiosyncratic shocks but not covariate shocks; (ii) labor diversification in Thailand and land diversification in Vietnam are used as *ex-post* coping strategies against covariate shocks but their shock-mitigating roles are insignificant; and (iii) land diversification in Thailand and labor diversification in Vietnam are helpful in improving per capita consumption when households face covariate shocks. Our findings suggest that facilitating access to credit, enhancing farm mechanization, and improving road quality in Thailand as well as promoting the development of local rural nonfarm sectors in Vietnam would benefit rural households in dealing with covariate shocks.

The second paper is about “Health shocks, household consumption, and over-indebtedness: Does having access to financial and insurance markets matter?” It investigates the impact of health shocks - defined as severe ill health events - on rural household’s consumption and indebtedness, and then examines the role of credit and health insurance in mitigating consequences of these adverse events. The findings show that rural households are unable to insure non-healthcare consumption and total consumption. Health shocks significantly push households into over-indebtedness through two channels: (i) reducing income from lower work earning capacity, and (ii) increasing informal borrowing to smooth consumption. Removing barriers in accessing health insurance and formal credit is recommended as it helps to lower the drop in consumption. In addition, having health insurance protects households from falling into over-indebtedness when severe illness strikes.

The third paper is on “Shocks, Agricultural Productivity and Natural Resource Extraction in Southeast Asia”. It uses survey data from four Southeast Asian countries, including Cambodia, Laos, Thailand and Vietnam to investigate the impact of shocks and agricultural productivity on natural resource extraction by rural households. The results show that weather shocks and market shocks force households to extract more natural resources. An increased agricultural productivity, however, discourages natural resource extraction. In addition, low education and low access to electricity are positively associated with natural resource extraction. These findings suggest that measures enhancing agricultural productivity should be prioritized, and more assistance and support to farmers for mitigating the severe effects of weather shocks and market shocks should be provided. Furthermore, accelerating farm mechanization, land defragmentation, rural electrification, supporting the development of communication systems and local markets, and promoting rural education should be encouraged.

The fourth paper is about “Remittances, Sanitation, and Child Malnutrition: Evidence from rural Southeast Asia”. This paper examines the impact of remittances on the propensity of

having a flush toilet by rural households, and its impact on child malnutrition in rural Thailand and Vietnam. The results show that remittances facilitate the adoption of a flush toilet, and children from households without a flush toilet suffer more from wasting, underweight, and stunting. Furthermore, the impact of having a flush toilet on child health is heterogeneous across different child groups. Younger, female children and children from poor households benefit significantly more from having a flush toilet. Supporting rural households to have flush toilets is thus recommended. In addition, promoting rural education and public water systems could also significantly reduce child malnutrition among rural households

Keywords: Southeast Asia, vulnerability, livelihood strategies, adaptive capacity

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List of Abbreviations

DFG	German Research Foundation
GDP	Gross Domestic Product
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PPP$	Purchasing Power Parity in USD
SGMM	System-General Methods of Moments
TVSEP	Thailand Vietnam Socioeconomic Panel
UN	United Nations
UNICEF	United Nations Children's Fund
VIF	Variance Inflation Factor
WB	World Bank

Chapter 1. Introduction

1. Problem Statement and Research Motivation

Shocks disrupt the flows of household income and consumption, and are responsible for welfare losses in developing countries (Arouri et al. 2015). They can be classified into idiosyncratic and covariate shocks (OECD 2009). The former affects a specific individual or household, while the latter affects a group of households, communities, regions or even an entire country. There is consensus that covariate shocks have more significant impacts on household welfare than idiosyncratic shocks (Dercon 2004). Catastrophic disasters such as storms, floods, and droughts can directly erode household resources, drive them into poverty traps, widen inequality, and worsen poverty among the already poor (Bui et al. 2014; Sawada and Takasaki 2017). However, certain idiosyncratic shocks such as health shocks could be dangerous to households as well. They can influence the resources available for household consumption, for example by limiting wage earning capacity (Gertler and Gruber 2002; Wagstaff 2007) or increasing medical expenses (McIntyre et al. 2006; Powell-Jackson and Hoque 2012). As a result, substantial financial losses may link health shocks to household vulnerability and impoverishment (Salari et al. 2019). Finding reliable strategies to improve adaptive capacity of rural households in developing countries and enhance their resilience to shocks is therefore a theme which has gained great interest of policy makers and scientific communities (Porter 2012)

Unfortunately, practical evidence for supportive interventions is limited due to several reasons. First, many of them are based on cross-sectional data, while the degree and the pattern of household vulnerability to shocks change over time (Klasen and Waibel 2013). Second, if panel data are available, detailed information on shocks and coping strategies are normally missing. Last, it is difficult to disentangle the causality as there is likely a two-way causation between

coping strategies and household economic outcomes (Arslan et al. 2018). This reverse causality may lead to a severe bias in examining the role and the effectiveness of such shock-mitigating measures.

Countries in Southeast Asia are known as economies with high economic growth rates and significant decreases in the poverty ratio in recent decades (World Bank 2020). However, they are commonly characterized by a large share of the population living in rural areas and highly depending on agricultural production. In addition, these countries are among the most vulnerable countries to climate risks (Eckstein et al. 2019). Given their non-existent or incomplete social protection system, it is likely that rural households in these countries are still highly vulnerable to different types of shocks (Grabrucker and Grimm 2020; Klasen and Waibel 2013; Lohman and Tobias 2015).

Against this background and by taking advantages of a rich panel dataset in Cambodia, Laos, Thailand, and Vietnam, the overall objectives of this thesis are to investigate and compare (i) the degree of household vulnerability to shocks and malnutrition, and (ii) the role of various adaptive livelihood strategies in mitigating shock impacts and improving household.

2. Structure and contribution of the dissertation

This dissertation is structured into five chapters. The first chapter introduces the overall research topic and highlights the contributions in each chapter.

Chapter 2 investigates the mitigating role of the livelihood diversification strategy in dealing with covariate and idiosyncratic shocks in Thailand and Vietnam. The research questions in this paper are:

1. What are the impacts of idiosyncratic and covariate shocks on rural household consumption and on land or labour diversification?

2. How effective are land and labour diversifications in mitigating the impacts of idiosyncratic and covariate shocks on household consumption?

This chapter applies dynamic models with System-Generalized Method of Moments estimators to control for endogeneity and employs a panel dataset obtained from five household surveys waves during 2007–2016. The chapter contributes to the existing literature by revisiting and positioning the relevance of specific livelihood diversification in rural areas of emerging economies.

Chapter 3 examines the relation between health shocks, household's consumption, and indebtedness, as well as assesses the mitigating role of credit and health insurance. It uses balanced panel household data obtained from four rural surveys in 2007, 2010, 2013, and 2016 in three provinces of Vietnam, namely Ha Tinh, Thua Thien Hue, and Dak Lak. Specifically, this chapter addresses the following research questions:

1. How do severe ill health events impact on rural households' consumption?
2. To what extent do severe ill health events push households into over-indebtedness?
3. Does access to credit and health insurance mitigate the negative impact of severe ill health events?

The chapter employs a heteroscedasticity-based identification strategy to control for the endogeneity issue. Its results add several important points to the existing literature. First, it evidences that using informal borrowing to smooth consumption when health shocks strike lead rural households to indebtedness. Second, having access to health insurance could reduce the household reliance on borrowing as a coping strategy.

Chapter 4 uses household survey data from four countries, including Cambodia, Laos, Thailand and Vietnam to investigate the links between shocks, agricultural productivity and

natural resource extraction. The chapter employs ordinary least squares (OLS) models to study the impact of shocks (weather shocks, market shocks, and health shocks) on natural resource extraction. Then, it uses the heteroscedasticity-based instrumental variable approach to study the impact of agricultural productivity on natural resource extraction. To our understanding, this is the first empirical study that has taken into account the effect of shocks on agricultural productivity and natural resource extraction simultaneously.

Chapter 5 examines the relation between remittances, sanitation, and child malnutrition in rural Thailand and Vietnam. This chapter addresses the following research questions:

1. To what extent do remittances impact rural households to have a private flush toilet?
2. How does a private flush toilet reduce child vulnerability to malnutrition?
3. Does the effect of having a private flush toilet on child health differ by age and gender of children, and welfare status of rural households?

This chapter uses panel household data obtained from four rural surveys in 2007, 2010, 2013, and 2016 in Thailand and Vietnam and also employs the heteroscedasticity-based instrumental approach to address the endogeneity issue. It adds to the existing literature results on the relation between migration, household sanitation, and child health.

3. Publication Status of Papers and Author's Contribution

Table 1 presents the overview and information about the publication status of all the papers included in the dissertation. Chapter 2 is published in the journal *Economic Change and Restructuring*, whereas chapters 3 and 4 are in the peer-review processes.

Table 1. List of papers included in the dissertation

Chapter	Authors	Title	Published in / Submitted to / Presented at
2	**Nguyen, D.L.,** Nguyen, T.T., and Grote, U.	Shocks, household consumption, and livelihood diversification: A comparative evidence from panel data in Thailand and Vietnam	Published in *Economic Change and Restructuring* (2022) https://doi.org/10.1007/s10644-022-09400-9
3	**Nguyen, D.L.**, Nguyen, T.T., Nguyen, T.T., and Grote, U.	Health shocks, Household consumption, and Over-indebtedness: Does having access to financial and insurance markets matter?	Under review at the *Journal of International Development* Presented at the Tropentag, Stuttgart, in 2021
4	Nguyen, T.T., Nguyen, T.T., Do, M.H., **Nguyen, D.L.,** and Grote, U.	Shocks, Agricultural Productivity and Natural Resource Extraction	Accepted by *World Development*
5	Nguyen, T.T., Nguyen, T.T., Do, M.H., **Nguyen, D.L.,** and Grote, U.	Remittances, Sanitation, and Child Malnutrition: Evidence from rural Southeast Asia	Submitted to the *Journal of Development Economics*

The Author's contribution to the chapters are as follows: Chapter 2 was mainly developed, analysed and written by the author whereas Trung Thanh Nguyen and Ulrike Grote supported the development of the initial idea and concept, the peer review process and proof-reading. Chapter 3 was jointly developed with Thanh T. Nguyen, Trung T. Nguyen, and Ulrike Grote. The author mainly performed the analysis and wrote the paper. Chapter 5 and 6 were the results of co-authorship with Thanh T. Nguyen, Trung T. Nguyen, Manh H. Do, and Ulrike Grote. The author wrote part of the literature review and the conceptual framework.

In addition, the author also took part in the field work of TVSEP 2016 by managing and supervising the household survey in Vietnam.

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Chapter 2. Shocks, household consumption, and livelihood diversification: A comparative evidence from panel data in rural Thailand and Vietnam

This chapter is published as:

Nguyen, D.L., Nguyen, T.T. & Grote, U. Shocks, household consumption, and livelihood diversification: a comparative evidence from panel data in rural Thailand and Vietnam. *Econ Change Restruct* (2022). https://doi.org/10.1007/s10644-022-09400-9

Chapter 3. Health shocks, household consumption, and over–indebtedness: Does having access to financial and insurance markets matter?

Abstract

Households in developing countries are often impaired in their economic opportunities by major health shocks. In this paper, we first (i) investigate the impact of health shocks defined as severe ill health events on rural household's consumption and indebtedness and then (ii) examine the role of credit and health insurance in mitigating consequences of these adverse events. We use four waves of a panel household dataset, spanning 10 years, from Vietnam and employ a heteroscedasticity-based identification strategy to address the endogeneity issue. The estimations show that rural households are unable to insure non-healthcare consumption and total consumption. Health shocks significantly push households into over-indebtedness through two channels: (i) reducing income from lower work earning capacity and (ii) increasing informal borrowing to smooth consumption. Removing barriers in accessing health insurance and formal credit is recommended as it helps to lower the drop in consumption. In addition, having health insurance protects households from falling into over-indebtedness when severe illness strikes.

Keywords: Health shocks; consumption smoothing; over-indebtedness; credit access; health insurance; heteroscedasticity-based identification

1. Introduction

Health shocks are the most common idiosyncratic shocks faced by households. They can influence the resources available for household consumption, for example by limiting wage earning capacity (Gertler & Gruber, 2002; Wagstaff, 2007) or increasing medical expenses (McIntyre et al., 2006; Powell-Jackson & Hoque, 2012). If consumption declines in response to a health shock, households experience a drop in resource endowment that they are unable to self-insure. In that case, access to external financial resources is needed. For example, households may rely on social networks (Dalton & LaFave, 2017; Park, 2006), remittances from migrated family members (Ambrosius & Cuecuecha, 2013; Berloffa & Giunti, 2019), or financial markets (Gertler et al., 2009; Islam & Maitra, 2012; DeLoach & Smith-Lin, 2018) to smooth consumption. Unfortunately, access to these resources is not always available, especially in low- and middle-income countries where rural households mainly work in the informal sector (Lanjouw, 2001; ILO, 2018), and where financial markets are non-existent or incomplete. As a result, financial loss from reduced labour supply and substantial healthcare expenditures may link health shocks to household vulnerability and impoverishment (Xu et al., 2003; Mataria et al., 2010; Salari et al., 2019; Nguyen, Trung Thanh et al., 2020).

The ability of rural households to insure consumption against health shocks is therefore a focal point of various studies in developing countries. However, empirical evidence has reached an inconclusive result. Some works find that households are able to smooth consumption (e.g. Genoni, 2012; Islam & Maitra, 2012; Mitra et al., 2016) while others present a contradictory finding (e.g. Weerdt & Dercon, 2006; Beegle et al., 2008; Gertler et al., 2009). These discrepant views lead to two more question that have not been well answered. The first is the linkage between severe illness and household's over-indebtedness. This causality might exist because financial distress can urge households with health shocks to trade-off between short-term consumption needs and long-term economic viability. Households may use costly coping

strategies that can retard economic opportunities such as increasing loan from informal money lenders or selling productive assets. Consequently, health shocks can push households into over-indebtedness by forcing them to accumulate more debt and decreasing their repayment capacity. Unfortunately, the causal effect of severe illness on household's over-indebtedness has not been studied in the literature.

The second is the mitigating role of financial and insurance markets when major health shocks strike. Informal coping strategies such as remittances, saving, and kindship might be effective in coping with minor health shocks but they are typically weak in protecting households from severe adverse shocks (Morduch, 1999). Access to financial markets is therefore expected to reduce household vulnerability. However, empirical results are counterintuitive. It is likely that financial instruments from formal markets only crowd out informal insurance arrangements rather than improving welfare. For example, Liu (2016) indicates that households with health insurance are able to fully insure consumption but the non-insured can do it as well. Similarly, Islam & Maitra (2012) find that having access to microcredit has a positive effect on consumption but this effect is no longer significant when they control for endogeneity. However, they also show a crowding out effect as microcredit helps households to reduce their livestock sales in response to health shocks. In this case, no or very little welfare has been gained because livestock is a certain type of precautionary saving while the interest rate of microcredit is commonly high.

Against this background, this paper aims to answer the following questions: (1) how do severe ill health events impact on rural households' consumption? (2) To what extent do severe ill health events push households into over-indebtedness? (3) Does access to credit and health insurance mitigate the negative impact of severe ill health events? Our study is undertaken in Vietnam, a low-middle income country in Southeast Asia where 76 percent of national jobs are without any employment contracts (Cunningham & Pimhidzai, 2018) and where the financial

system shows some deficiencies as can be derived from its ranking at position 60 out of 141 in the Global Competitiveness Report 2019 (Klaus, 2019). In 2009, the first Health Insurance Law in Vietnam came into effect, and health insurance has been opened to rural households under the individual voluntary scheme. In mid-2014, the Law was amended and compulsory enrolment has been required for the entire population. Accordingly, family-based health insurance has been introduced in rural areas in order to expand its coverage rapidly (Le et al., 2020). However, the enrolment is still low (Nga et al., 2018). To capture this transition period, we use a panel dataset that was collected from the same rural households over four survey waves in the period from 2007-2016.

Our work contributes to the literature in a number of ways. First, we shed new light on measuring health shocks. We identify health shocks as severe ill health events that actually cause significant income losses to rural households. This is different from previous studies where health shocks were mainly defined through self-reported symptoms, new diagnoses, or limitation on daily activities (e.g. Gertler & Gruber, 2002; Wagstaff, 2007; Islam & Maitra, 2012; Mitra et al., 2016). In fact, these measures represent changes in health status rather than indicating actual income shocks that hit households. Our measure, therefore, ensures to capture major but not minor health deteriorations for the analysis.

Second, we are the first to quantify household's financial hardship as a consequence of health shocks. We do that by linking the recently developed concept of over-indebtedness (Schicks, 2013a; D'Alessio & Iezzi, 2013; Federico & Daniela, 2019) to our framework. We point out that health shocks lead to the reduction of household capacity to pay off the debt. Meanwhile, informal smoothing mechanism such as taking a loan in response to health shocks is one of the reasons that burden households.

Third, we elaborate a different way in examining the effects of health insurance on protecting financial losses. Health insurance is expected to protect households from financial distress caused by sudden incursion of medical expense. A common approach is to measure its effects on out-of-pocket health expenditure directly[1]. Alternative indicators can be the probability of incurring catastrophic health expenditure (defined as out-of-pocket payment exceeding a certain threshold as a share of total household expenditure or income (Xu et al., 2003)) or the probability of impoverishment due to catastrophic health expenditure (Fan et al., 2012; Aryeetey et al., 2016). However, empirical results from these approaches are not convincing. There has been a considerable number of studies that show that health insurance has very limited or no effect on household healthcare expenditure in low- and middle-income countries (Erlangga et al., 2019). There are two reasons that can explain this outcome. First, a large number of these studies focus on the poor but the average healthcare expenditure cannot be lower for the insured poor than the uninsured poor (Acharya et al., 2013). Second, healthcare expenditures in low- and middle-income countries include not only medical expenses but also other related costs such as service charge for additional medicinal requirements, equipment, transportation, and informal payments to doctors (Nguyen, 2012; Matsushima et al., 2020). In this study, we estimate the effects of health insurance on household's non-healthcare consumption and on the probability of being over-indebted. We find that health insurance helps to lower the drop in non-health consumption and reduce the probability of falling into over-indebtedness when health shocks hit households.

[1] According to the definition of the World Health Organization, out-of-pocket health payments refer to the payments made by households at the point they receive health services. These include doctor's consultation fees, purchases of medication and hospital bills.

2. Conceptual framework and empirical strategy

2.1 Conceptual framework

A common way to measure the degree of insurance against health shocks is to measure the effects of these shocks on consumption. Our study is, therefore, motivated by the full insurance consumption model (Cochrane, 1991; Townsend, 1994). This model has largely been used to examine the impact of health status on household outcome in low-and middle-income countries (see Alam & Mahal (2014)). Suppose that household *h* has an expected lifetime utility function from the consumption of a stream of goods *C* in event *s* at time t

$$U^h = \sum_{t=1}^{\infty} \beta^t \sum_{s=1}^{S} \pi_{st} u\left(c_{st}^h; \theta_{st}^h\right) \tag{1}$$

where θ_{st}^h compounds factors that change preference, and β if the discount factor. Household *h* has an exogenous endowment of the consumption good

$$y_{st}^h = \overline{y_t^h} + \upsilon_{st}^h + \varepsilon_{st}^h \tag{2}$$

where $\overline{y_t^h}$ is a deterministic component of output, υ_{st}^h denotes aggregate shocks, and ε_{st}^h represent idiosyncratic shocks to household's endowment.

The social planer maximizes the weighted sum of expected utility of the N households in a community, given by the objective function (3) with λ^h being household *h*'s Pareto weight, by choosing an allocation of consumption across individual households subject to the aggregate endowment in equation (4)

$$Max \sum_{h=1}^{N} \lambda^h \sum_{t=1}^{\infty} \beta^t \sum_{s=1}^{S} \pi_{st} u\left(c_{st}^h; \theta_{st}^h\right) \tag{3}$$

$$\sum_{i=1}^{N} c_{st}^{h} = \sum_{i=1}^{N} y_{st}^{h} \tag{4}$$

Assuming that the utility function is exponential

$$u\left(c_{st}^{h};\theta_{st}^{h}\right) = -\frac{1}{\sigma}\exp\left[-\sigma\left(c_{st}^{h}-\theta_{st}^{h}\right)\right], \qquad \sigma > 0 \tag{5}$$

By taking a derivative with respect to c_{st}^{h}, the first order conditions for the problem maximization in equation (3) subject to the constraint in equation (4) is

$$\hat{\mu}_t = \lambda^h \exp\left[-\sigma\left(c_{st}^{h}-\theta_{st}^{h}\right)\right], \tag{6}$$

where $\hat{\mu}_t = \mu_t / \beta^t \pi_t$ and μ_t denotes the Lagrange multiplier associated with the aggregate endowment constraint (4) at time *t*. If we take the logarithm of equation (6) and aggregate over N households, it yields consumption for household *h* being

$$c_t^h = c_t^A + \frac{1}{\sigma}\left(\log\lambda^h - \lambda^A\right) + (\theta_t^h - \theta_t^A), \tag{7}$$

where $\lambda^A = \frac{1}{N}\sum_{i=1}^{N}\log\lambda^h,\ \ c_t^A = \frac{1}{N}\sum_{i=1}^{N} c_t^h,\ \ \theta_t^A = \frac{1}{N}\sum_{i=1}^{N}\theta_t^h$

Equation (7) implies that the individual household consumption is positively associated with the aggregate consumption, which varies by state and over time. The sign of $\log\lambda^h - \lambda^A$ represents consumption for household *h* being above or below the average community consumption. By taking the first difference of equation (7), the individual fixed effect $\log\lambda^h - \lambda^A$ is removed, and it yields:

$$c_{t+1}^{h} - c_{t}^{h} = c_{t+1}^{A} - c_{t}^{A} + \left[(\theta_{t+1}^{h} - \theta_{t}^{h}) - (\theta_{t+1}^{A} - \theta_{t}^{A}) \right] \quad (8)$$

Or $$\Delta c_{t}^{h} = \Delta c_{t}^{A} + (\Delta \theta_{t}^{h} - \Delta \theta_{t}^{A}) \quad (9)$$

The major implication from equation (9) is that changes in individual household consumption are determined by changes in aggregate consumption rather than by changes in idiosyncratic variables. This has often been tested in low- and middle-income countries by examining whether informal risk sharing strategies are sufficient to smooth consumption over health shocks (Alam & Mahal, 2014). If not, then there might be a potential welfare gain from providing formal instruments such as health insurance. Otherwise, crowding out effects of formal instruments will occur and little or no welfare will be obtained (O'Donnell, 2016).

2.2 Empirical strategy

2.2.1 Impact of health shocks on household income and consumption

We employ a fixed effects model to capture the impact of health shocks on household's economic outcomes. We first estimate health shocks on household income to see whether a reduction in labour supply would lead to a reduction in earned income and total income. The estimation equation is follows:

$$I_{it} = \alpha_0 + \alpha_1 S'_{it} + \alpha_2 F'_{it} + \alpha_3 X'_{it} + \mu_i + \varepsilon_{it} \quad (10)$$

where subscripts *i* and *t* denote household and survey year, respectively. *I* represents the dependent variables for the estimated equation, which is the log of per capita household's total income, per capita off-farm income, and per capital agricultural income. *S'* is a vector of health shocks. *F'* is a vector of dichotomous variables representing household access to external financial resources such as informal credit, formal credit, remittances, and health insurance. *X'*

represents a vector of household and village characteristics. Other invariant and variant unobserved characteristics of the households were represented by μ and ε, respectively. The coefficient of the health shocks α_1 is of our interest.

We then assess the impact of health shocks on household consumption. Specifically, the per capita consumption of household *i* in year *t* (C_{ijt}, in ln form) is a function of a vector of health shocks, a vector of household access to external financial resources, a vector of household and village characteristics, and a household fixed effect u_i and an error term v_{it}.

$$C_{it} = \beta_0 + \beta_1 S'_{it} + \beta_2 F'_{it} + \beta_3 X'_{it} + u_i + v_{it} \qquad (11)$$

In equation (11), C_{it} denotes the per capita total consumption, per capita non-healthcare consumption, and per capita health care expenditure. The coefficient of interest β_1 illustrates whether health shocks would increase household expenditure for healthcare while decrease non-health consumption. If the per capita non-health consumption is decreased, the hypothesis of full insurance consumption theory is rejected.

2.2.2 Impact of health shocks on credit access

We assume that households with health shocks may increase their access to formal and informal credit to finance for health care expenditure and non-health consumption. The equation (12) below describes a possible relationship between health shocks and household access to credit:

$$K_{it} = \lambda_0 + \lambda_1 S'_{it} + \lambda_2 F'_{it} + \lambda_3 X'_{it} + \eta_i + \varsigma_{it} \qquad (12)$$

where K_{it} is the vector representing weather a household has an access to credit. Since K_{it} includes formal and informal credit which can be substituted to each other, we therefore use different scenarios to control them in estimating equation (12)

2.2.3 Impact of health shocks on household over-indebtedness

Being engaged in a new debt or reduced repayment capacity may bring rural households facing with health shocks to a deep debt burden. We use equation (13) to estimate the association between health shocks and household's over-indebtedness.

$$O_{it} = \gamma_0 + \gamma_1 S'_{it} + \gamma_2 F'_{it} + \gamma_3 X'_{it} + \omega_i + \xi_{it} \quad (13)$$

In equation (13) we use different levels of over-indebtedness representing by O_{it} to evaluate the severity of health shocks on household indebted situation.

2.2.4 Effect of access to credit and health insurance

The second set of econometric models is used to examine the role of formal credit, informal credit, and social health insurance in mitigating the effects of health shocks. The specification is described in equation (14) which is an extended version of above equations

$$Y_{it} = \varphi_0 + \varphi_1 S'_{it} + \varphi_2 F'_{it} + \varphi M'_{it} * S'_{it} + \varphi X'_{it} + \psi_i + \zeta_{it} \quad (14)$$

where $M_{it}' \in F_{it}'$ and M' is a vector of access to formal credit, informal credit, and health insurance, Y_{it} represents the log of per capita household's consumption, per capita non-health consumption, per capita healthcare expenditure, and the probability of over-indebtedness.

A major concern in estimating equations (10) and (14) is the presence of multiple endogenous variables. First, health shock is an endogenous variable because there exists a potential reverse causality between health shocks and outcome variables (Genoni, 2012; Mitra et al., 2016; Mohanan, 2013). For instance, health shocks can lower household's income and consumption, and these reductions can feed back into individual health status through decreasing essential nutrient intake. Similarly, health shocks might cause over-indebtedness but severe indebtedness

can be stressful to household members and negatively influence their physical and mental health (Turunen & Hiilamo, 2014; Angel, 2016). Second, variables representing coping mechanisms (i.e. formal and informal credit, remittances, and health insurance) are also endogenous. It is possible that these variables are associated with unobserved determinants of household welfare and status of over-indebtedness (Islam & Maitra, 2012; Liu, 2016). Failing to control for these endogeneity concerns will lead to biased and invalid estimates.

To address these sources of bias, it is suggested to employ instrumental variables (IVs) that are highly correlated with health shocks (e.g. Genoni, 2012) and/or coping strategies (e.g. Islam & Maitra, 2012) while being uncorrelated with outcome variables. However, finding such valid standard instruments for multiple endogenous variables is very difficult. An alternative approach is the use of internal instruments generated from the models. For example, dynamic estimators that are constructed from the generalized method of moments use lagged values of regressors as instruments for endogenous variables (Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998). Yet, dynamic estimators strictly require uniform panel data with regular spacing along the time dimension. That means the successive waves of observed data must be consistent with successive periods as defined by the underlying data generating process (Millimet & McDonough, 2017). Given our panel data were collected triennially while variables are measured annually, the application of dynamic panel data estimators may lead to biased estimation.

We therefore follow Lewbel (2012) to implement the heteroscedasticity-based instruments method to address the endogeneity issue. This two-stage estimator bypasses exclusion restrictions which are often carried out by standard IVs estimators but exploits heteroscedasticity for identification. Furthermore, it is applicable even if outcome variables and endogenous regressors are binary (Lewbel, 2018). According to Lewbel (2012), identification is achieved if there exists a vector of exogenous variables Z and the errors are heteroscedastic.

In our case, $Z \in X$ with X being a vector of explanatory variables that represent household characteristics. In the first stage, each endogenous variable in equations (10) and (11) is regressed on the Z vector, and the vector of residuals $\hat{\xi}$ is retrieved. Using these estimated residuals, $(Z_i - \bar{Z}_i)\hat{\xi}$ is constructed for Z_i where $\bar{Z}$ is the mean of Z_i (and i denotes the element of the Z vector). In the second-stage, $(Z_i - \bar{Z}_i)\hat{\xi}$ is used like standard instrumental variables. This estimator will be more efficient if additional external instruments are employed (Baum & Lewbel, 2019). We thus follow prior studies (e.g. Acosta, 2006; Mansuri, 2006; Bui et al., 2014; Hoang et al., 2014) to employ the average number of members with severe ill health per household, the share of households with access to formal credit, informal credit, remittances, and health insurance at village level as additional instruments.

To diagnose the identification, three tests for over-identification, under-identification, and weak identification are conducted. The Hansen J statistic is computed as a test of over-identifying restrictions. The Kleibergen-Paap rk Wald statistic is used to test whether instruments are irrelevant (under-identification). And, the Cragg-Donald statistic is employed to test whether instruments are weak. Results of these tests can be found at the end of each table from Table 3 to Table 8. It is worth to note that the reported numbers for under-identification and over-identification are p-values while weak identification is represented by F statistics. According to Staiger and Stock's (1997) rule of thumb, weak identification should not be a problem if F statistics is at least 10.

3. Data and measures

3.1 Data source

Data for our study are taken from field surveys under the research project "*Thailand Vietnam Socioeconomic Panel*"[2]. The survey targets households with low average per capita income and high dependence on agriculture. In addition, climate-related risks and poor infrastructure prevail in the survey sites (Hardeweg et al., 2013). The procedure for primary data collection is based on the guidelines of the UN Department of Economic and Social Affairs (United Nations, 2008). In Vietnam, three rural provinces including Ha Tinh, Thua Thien Hue in the Central Coast, and Dak Lak in the Central Highlands were chosen as study sites. First, communes in these provinces were determined based on the population share. Second, two villages per commune were selected proportionately to the size of the population in the commune which amounted to 220 villages in total. Last, ten households were randomly selected in each sampled village with equal probability selection.

Two structured questionnaires are used for data collection. The village questionnaire is used to collect information about the villages such as location, economic activities, public infrastructure, and social structure. The household survey captures household-specific information. It is structured in nine sections including socio-demographic data of the household and its members (section 2), detailed information on shocks and risks (section 3), on land and other natural resources and agricultural production (section 4), off-farm employment and non-farm self-employment (sections 5 and 6), household lending, borrowing, insurance, and other public transfers (section 7), household consumption, including food, nonfood and other

[2] Project information and both village and household questionnaires are available at www.tvsep.de.

expenditures (section 8), and household wealth (section 9). The collected data refers to the last 12 months (from May of the previous year to April of the survey year).

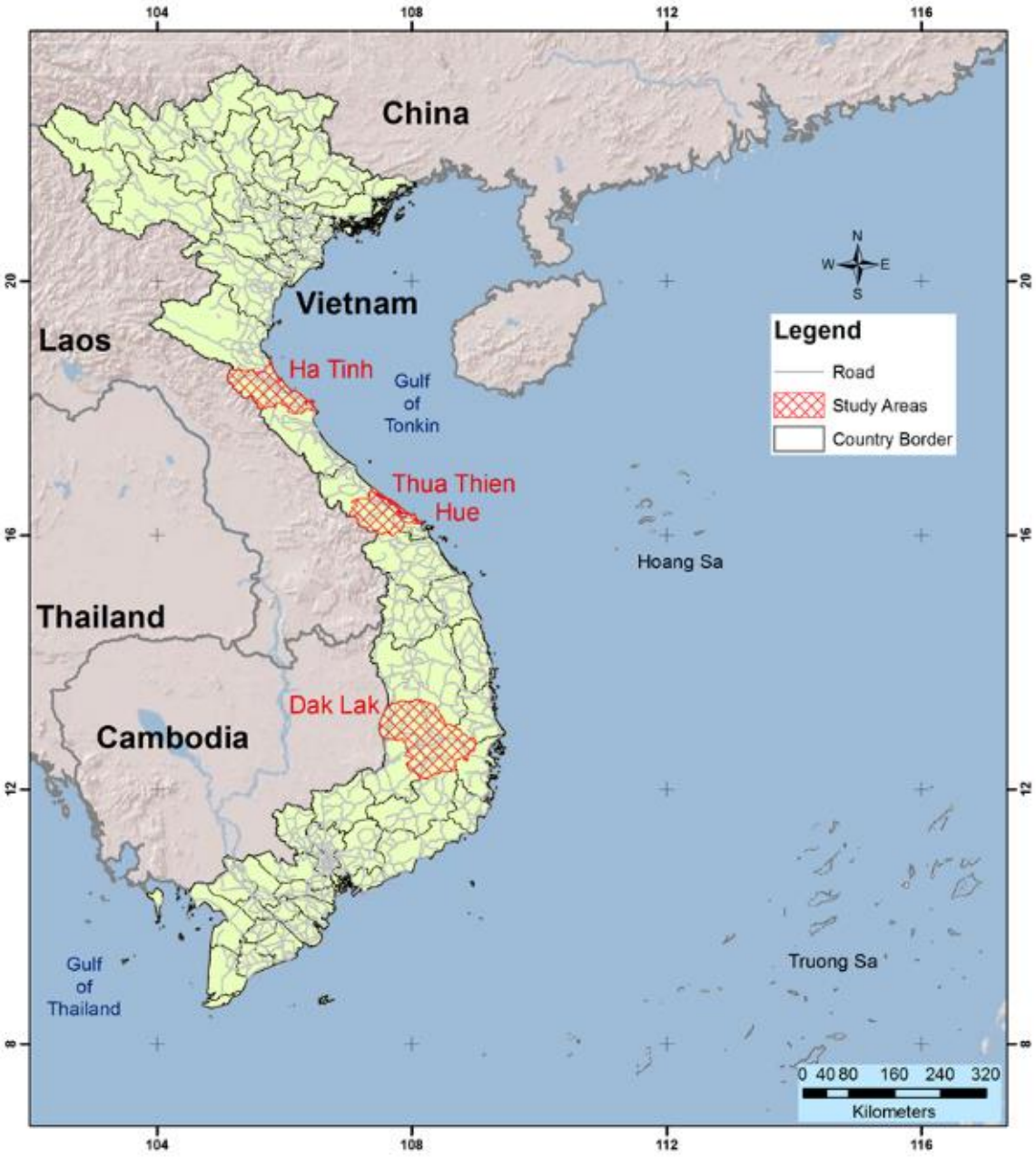

Figure 1: Study sites in Vietnam (adapted from Do et al. (2019))

In section 2, there is a subsection where details of illnesses experienced by each individual household member are collected such as type of illness, duration of illness, place for treatment, and type of treatment. In section 3, detailed information about every shock that hit a household

during the survey year is provided, including type of event, time it occurs, losses in income and assets due to shock, and extra expenditure due to shock. Based on the financial loss caused by each shock, households were asked to classify its severity into four categories, i.e. high, medium, low, and no impact. In the case of health shocks, section 2 and section 3 are linked by the unique identifiers for household members.

We use four waves of the panel survey which were conducted in 2007, 2010, 2013, and 2016. The pre-determined sample includes 7906 rural households, but some of them did not attend every survey wave[3]. To avoid the effect of attrition on our estimation, we construct a balanced panel dataset by dropping households that did not participate in all four survey waves and households with missing values for important variables. The final sample used for the analysis includes 7304 observations with 1826 households from each survey wave.

3.2 Measuring health shocks

Measuring health shocks is not trivial in practice. Previous studies mainly identified health shocks by using one or more measures that reflect health changes. For example, they can be captured by "days unable to carry out regular activities because of illness/injury", "days in bed due to illness/injury", 'hospitalization", and "whether any household member was sick" (Islam & Maitra, 2012; Mitra et al., 2016). These health change measures were generally classified by Currie & Madrian (1999) into eight categories, including: 1) self-reported health status (most often whether someone is in excellent, good, fair, or poor health); 2) whether there are health limitations on ability to work; 3) whether there are other functional limitations such as problems with activities of daily living; 4) the presence of chronic and acute conditions; 5) the utilization of medical care; 6) clinical assessments of such things as mental health or alcoholism; 7)

[3] Detailed information on causes for non-response and measurement errors in these households panel surveys can be found in Phung et al. (2015)

nutrient status (e.g. body mass index); and 8) expected or future mortality. However, these measures refer to the changes in ability and desire to work rather than to health shocks (Currie & Madrian, 1999). Changes in health status may cause temporary reduction in labour supply and then income variability but may not be income shocks that bring financial hardship on households. Thus, estimating the impact of health shocks can be misleading. It is likely that households in low- and middle-income countries are capable to fully insure consumption against minor illness (Wagstaff, 2007; Genoni, 2012; Islam & Maitra, 2012; Sparrow et al., 2014; Mitra et al., 2016), even if they have no health insurance (Liu, 2016). Meanwhile, they are unable to smooth their consumption when a major illness occurs (Gertler & Gruber, 2002).

Our identification of health shocks attempts to cover this gap from previous studies. We use two steps to double confirm the occurrence of severe ill health events as health shocks. First, we follow Tran et al. (2015) and consider illnesses that made household members unable to pursue their occupation for at least four weeks, as severe ill health events. Second, if households report that they have moderate or severe impact due to these illnesses, then major health shocks are identified. This combination allows us to ensure the shock is major, not minor illness (Gertler & Gruber, 2002). In addition, setting a threshold for severe illness makes health shocks more comparable across households. Details on the identification of health shocks are presented in Table 1.

Table 1 shows, the number of households having members unable to perform their occupations less than four weeks account for almost 17 percent and from four weeks and more is 24 percent. Meanwhile, the number of households reported sizeable income shocks due to illness is only 16.5 percent. By matching rows (3) and (4), we identify 553 households with major health shocks, accounting for 7.6 percent of the total surveyed households (row 6). Among these households with severe health shocks, 82 percent are in the working age (18-65).

Table 2: Households with health shocks during 2007-2016

			2007	2010	2013	2016	2007-2016
1. Total households (HHs)		No	1826	1826	1826	1826	7304
2. HHs have members unable to pursue occupation less than 4 weeks		No	236	319	333	343	1231
		%	12.9	17.5	18.2	18.8	16,8
3. HHs have members unable to pursue occupation at least 4 weeks		No	506	425	423	385	1739
		%	27.7	23.4	23.1	21.1	23.8
4. HHs with income shocks from illness		No	290	346	284	282	1202
		%	15.8	19.0	15.6	15.5	16.5
5. HHs have health shocks determined by (2) & (4) †		N	69	103	73	92	337
		%	3.8	5.6	4.0	5.0	4.6
6. HHs have health shocks determined by (3) & (4)		No	142	160	133	118	553
		%	7.8	8.8	7.3	6.5	7.6
Age range of illness	<18 years old	No	14	11	6	12	43
		%	9.9	6.9	4.5	10.2	7.8
	18-65 years old	No	112	135	107	102	455
		%	78.9	84.4	80.5	86.4	82.4
	>65 years old	No	27	27	30	28	112
		%	19	16.9	22.6	23.7	20.3

Notes: † these households were able to completely smooth consumption - see Appendix 2.

To validate the identification of health shocks, we also measure the effects of ill health events that make household members unable to perform their occupations less than four weeks but were reported as source of income shocks (row 5) on household consumption. The result in Appendix 2 shows that the per capita total consumption and per capita non-healthcare consumption are not negatively influenced by these events. This implies that rural households are capable to fully insure their consumption against such illnesses. In other words, these ill health events are minor, not major health shocks

3.3 Measuring over-indebtedness

At household level, over-indebtedness is commonly related to the responsibility and ability to pay off debts. It arises when debts exceed the optimal debt level (Elliot & Lindblom, 2019). Over-indebtedness can be measured as a quantitative threshold that signals an unsustainable spending behaviour (e.g. consumption/income ratio) or an unhealthy level of debt (debt/assets

ratio) or inability to service debt (e.g. debt payment/income ratio) (Betti et al., 2007). It can also be defined in qualitative terms such as a reported debt burden (Schicks, 2013a).

In this paper, we follow D'Alessio & Iezzi (2013) to use the debt service to income ratio (DSR) as an outcome variable to represent over-indebtedness. This indicator is widely recognized as a standard measure to interpret level of indebtedness (European Commission, 2008; D'Alessio & Iezzi, 2013). However, there is still no consensus regarding the threshold of over-indebtedness at household level. Empirical evidence from D'Alessio & Iezzi (2013), Schicks (2013b), and Chichaibelu & Waibel (2017) suggests that over-indebtedness occurs when DSR ranges from 0.3 to 0.5. That means a household is over-indebted if its annual debt payment accounts for more than 30 to 50 percent of annual income. We employ this range to construct a set of three over-indebtedness indicators with DSR equalling 0.3, 0.4, and 0.5.

3.4 Summary statistics

Apart from indicators representing over-indebtedness, we also employ different categories of per capita income and per capita consumption as outcome variables. They include total income, off-farm income, farm income, total consumption, non-healthcare consumption, and health care expenditure. The description of the outcome variables is presented in Panel A of Table 2. Between 2007 and 2016, the average per capita income had increased 2.8 times with major contributions from off-farm income. Correspondingly, the average per capita total consumption and non-healthcare consumption increased about two times while health care expenditure tripled. Meanwhile, the percentage of indebted households remained unchanged at DSR levels of 0.3 and 0.4 between 2007 and 2016. There was a decrease in number of households with DSR of 0.5, from 10.6 percent in 2007 to 8.4 percent in 2016.

Panel B of Table 2 shows explanatory variables representing characteristics of rural households and villages. At household level, we use age of household head, household size and labour, and

the highest number of school years achieved by household members to represent household's demographics. Household's productive assets are represented by farmland area, number of motorbikes, and number of livestock. The number of mobiles captures household's social capital because mobile phones, especially smartphones enable communication but also support information flows (Nguyen, Trung Thanh et al., 2017; Hartje & Hübler, 2017).

Table 3: Descriptive statistics

		2007-2016		2007		2016		2016/2007
		Mean	SD	Mean	SD	Mean	SD	
Panel A: Outcome variable								
Total income pc	PPP$	1756.3	(2601.6)	998.1	(1,991.7)	2,838.9	(3,266.1)	1,840.76***
Off-farm income pc	PPP$	753.3	(1498.3)	430.1	(1,016.2)	1,119.9	(2,083.1)	689.82***
Agricultural income pc	PPP$	636.4	(1659.1)	431.8	(1,568.8)	975.6	(2,001.6)	543.7***
Other income pc	PPP$	409.7	(1138.4)	136.2	(572.9)	743.4	(1,567.3)	607.24***
Total consumption pc	PPP$	1480.4	(1265.8)	988.5	(583.8)	2,048.7	(1,728)	1,060.22***
Non-health consumption pc	PPP$	1402.4	(1177.5)	942.7	(567.9)	1,917.5	(1,555.8)	974.77***
Health expenditure pc	PPP$	77.6	(294.4)	45.8	(76.9)	131.2	(496.1)	85.45***
debt-to-income ratio= 0.5		10.1	(30.2)	10.6	(30.8)	8.4	(27.8)	-2.14*
debt-to-income ratio= 0.4		11.6	(32.0)	11.0	(31.3)	10.3	(30.5)	-0.6
debt-to-income ratio= 0.3		13.8	(34.4)	11.8	(32.3)	13.1	(33.7)	1.26
Panel B: Explanatory variable								
Age	year	51.6	(13.2)	47.5	(13.2)	55.3	(12.5)	7.82***
Education	year	10.6	(3.7)	10.0	(3.5)	10.4	(3.9)	0.41***
HH size		4.1	(1.7)	4.4	(1.7)	3.8	(1.6)	-0.66***
HH labour		2.7	(1.4)	2.7	(1.4)	2.6	(1.4)	-0.14***
Farmland	ha	0.7	(1.0)	0.6	(1.0)	0.8	(1.5)	0.14***
Motorbike	no.	1.1	(1.0)	0.7	(0.7)	1.5	(1.1)	0.79***
Mobile	No.	1.5	(1.5)	0.2	(0.5)	2.5	(1.5)	2.25***
Livestock	TLU	1.0	(1.6)	1.1	(1.7)	1.0	(1.6)	-0.1
Share of HHs with formal credit	%	26.3	(44.0)	24.6	(43.1)	24.8	(43.2)	0.22
Share of HHs with informal credit	%	23.4	(42.3)	23.9	(42.6)	24.4	(42.9)	0.49
Share of HH with health insurance	%	31.8	(46.6)	20.4	(40.3)	35.0	(47.7)	14.52***
Share of HHs has remittances	%	22.1	(41.5)	12.3	(32.9)	26.2	(44.0)	13.92***
Share of HH with health shocks	%	7.6	(26.4)	7.7	(26.7)	6.5	(24.6)	-1.26
Share of HHs with weather shocks	%	37.8	(48.5)	37.2	(48.4)	30.8	(46.2)	-6.41***
Road quality		1.8	(1.0)	2.1	(1.0)	1.6	(1.0)	-0.51***
Distance to town	km	12.0	(9.4)	13.4	(10.1)	10.7	(9.8)	-2.67***
Number of observations		7304		1826		1826		

Notes: *, **, *** significant at 10, 5, 1% level; HH = household; pc = per capita; SD = Standard deviation

To control for financial assets, we use binary variables representing households with remittances, access to credit and health insurance. Remittances not only provide additional funds to dampen the effects of health shocks but also accelerate household's economic opportunities and improve living standards (Ambrosius & Cuecuecha, 2013; Berloffa & Giunti, 2019; Beuermann et al., 2016). Similarly, having access to financial markets minimizes the negative effect of health shocks on consumption while ameliorating household's asset accumulation. We distinguish between access to credit from formal and informal sources because their impacts on household expenditure and indebtedness may differ (Schindler, 2010; Schicks, 2014; Viet Nguyen & van den Berg, 2014; Phan et al., 2019). We use a dummy variable to represent whether a household had experienced weather shocks in the last 12 months to capture this covariate type of shock. This is because Vietnam is among the most vulnerable countries to weather risks (Eckstein et al., 2018) and natural disasters have negatively influenced rural household welfare (Arouri et al., 2015). At village level, we employ the quality of village's road and the distance from village to town centre to represent local community's infrastructure. Rural infrastructure plays an important role in building household resilience against shocks and stresses (Cuong et al., 2015). More detailed definitions of explanatory variables can be found in Appendix 1.

As shown in Table 2, an average rural household in our research areas has around four nucleus members and at least one of them graduated from secondary school which required nine years of school attendance. The farmland area cultivated by a household is around 0.7 ha, relatively small. The proportion of households with access to either formal or informal credit sources is quite similar, accounting for a quarter and remaining unchanged between 2007 and 2016. Meanwhile, the number of households with family members being protected by either voluntary or compulsory health insurance had increased from 20 percent in 2007 to 35 percent in 2016. Similarly, the percentage of households that received remittances increased from 12.3 to 26.3

percent. Natural disasters are an important risk that rural households in Central Vietnam have to cope with. On average, 38 percent of all households experienced weather shocks during 2007-2016.

4. Results and discussion

4.1 Impact of health shocks on household income and consumption

Table 3 presents effects of health shocks and other control factors on different household income indicators. Columns 1 and 2 show that health shocks do have some negative effects on per capita total income and per capita farm income but they are not statistically significant. Column 3 illustrates that health shocks are responsible for a reduction of per capita off-farm income by 42.5 percent. Declining household income due to health shocks commonly observed from studies in low- and middle-income countries (Alam & Mahal, 2014). A significant reduction in off-farm income of rural households reveals the growing role of non-agricultural employment. According to the World Bank (2016) the share of income from wage employment in total household income has rapidly increased in Vietnam, from 28 percent in 2008 to more than 44 percent in 2014. However, most wage employment for rural labourers still takes place in the informal sector (General Statistics Office of Vietnam, 2018). Without compensation, earnings from non-farm activities become the most vulnerable income component when health shocks hit households. Moreover, the decrease in off-farm income may not only come from off-working days of ill health members but also from those who have to be caregivers.

Table 4 shows results on the impacts of health shocks on household consumption. It can be seen that per capita total consumption and per capita non-healthcare consumption decrease by 6 and 6.5 percent, respectively when health shocks hit households.

Table 4: Impact of health shocks on household income

	(1) Total income	(2) Farm Income	(3) Off-farm income
Health shocks	-0.098	-0.011	-0.425**
	(0.123)	(0.166)	(0.170)
Formal credit	-0.123	0.050	0.101
	(0.122)	(0.171)	(0.148)
Informal credit	-0.116	-0.415**	0.125
	(0.137)	(0.179)	(0.160)
Health insurance	0.141	0.166	0.116
	(0.131)	(0.168)	(0.157)
Remittances	0.593***	0.269*	-0.123
	(0.107)	(0.157)	(0.140)
Age	-0.007*	-0.010*	-0.012**
	(0.004)	(0.006)	(0.006)
Education	0.010	0.029**	0.117***
	(0.009)	(0.013)	(0.014)
Household size	-0.116***	-0.116***	0.163***
	(0.022)	(0.031)	(0.033)
Household labor	0.022	-0.050	0.197***
	(0.025)	(0.032)	(0.039)
Farm land (ha)	0.021	0.202***	-0.028
	(0.021)	(0.037)	(0.031)
Motorbike	0.038	0.079*	0.213***
	(0.030)	(0.042)	(0.048)
Mobile phone	0.076***	0.066***	0.177***
	(0.018)	(0.024)	(0.028)
Livestock (TLU)	0.015***	0.044***	0.024***
	(0.005)	(0.011)	(0.007)
Village road quality	0.052*	0.074*	-0.032
	(0.028)	(0.039)	(0.031)
Distance to town	-0.003	-0.002	-0.013**
	(0.004)	(0.005)	(0.006)
Weather shocks	-0.281***	-0.243***	-0.018
	(0.039)	(0.050)	(0.056)
Year 2	0.848***	0.682***	0.343***
	(0.069)	(0.085)	(0.073)
Year 3	0.762***	0.471***	0.573***
	(0.072)	(0.105)	(0.087)
Year 4	1.449***	1.024***	0.703***
	(0.083)	(0.108)	(0.106)
Number of observations	7304	7304	7304
F-test	113.70	38.01	46.55
P-value	0.00	0.00	0.00
Under-identification test	0.00	0.00	0.00
Over-identification test	0.15	0.18	0.61
Weak instrument test	12.43	12.43	12.43

Notes: *, **, *** significant at 10, 5, 1% level; robust standard errors clustered at village level in parentheses

Table 5: Impact of health shocks on household consumption

	(1) Total consumption	(2) Non-health consumption	(3) Health expenditure
Health shocks	-0.060**	-0.065**	0.315*
	(0.030)	(0.029)	(0.191)
Formal credit	-0.040	-0.026	-0.005
	(0.027)	(0.027)	(0.187)
Informal credit	0.052*	0.046	0.693***
	(0.029)	(0.029)	(0.164)
Health insurance	0.056**	0.074***	0.452***
	(0.027)	(0.028)	(0.166)
Remittances	0.051*	0.059**	0.150
	(0.029)	(0.028)	(0.141)
Age	-0.000	-0.001	0.017***
	(0.001)	(0.001)	(0.006)
Education	0.010***	0.010***	0.028*
	(0.002)	(0.002)	(0.016)
Household size	-0.151***	-0.148***	-0.125***
	(0.005)	(0.006)	(0.035)
Household labor	0.000	-0.000	-0.012
	(0.005)	(0.005)	(0.034)
Farm land (ha)	0.031***	0.031***	0.089***
	(0.004)	(0.005)	(0.034)
Motorbike	0.109***	0.117***	-0.062
	(0.007)	(0.007)	(0.040)
Mobile phone	0.042***	0.039***	0.130***
	(0.004)	(0.004)	(0.028)
Livestock (TLU)	0.004**	0.005**	-0.006
	(0.002)	(0.002)	(0.007)
Village road quality	-0.002	0.003	-0.105***
	(0.005)	(0.006)	(0.034)
Distance to town	-0.000	-0.000	-0.029***
	(0.001)	(0.001)	(0.006)
Weather shocks	-0.018**	-0.014	0.025
	(0.009)	(0.009)	(0.051)
Year 2	0.092***	0.089***	-0.635***
	(0.013)	(0.012)	(0.096)
Year 3	0.241***	0.245***	-0.651***
	(0.016)	(0.016)	(0.100)
Year 4	0.353***	0.335***	0.155
	(0.018)	(0.018)	(0.099)
Number of observations	7304	7304	7304
F-test	353.95	293.13	25.11
P-value	0.00	0.00	0.00
Under-identification test	0.00	0.00	0.00
Over-identification test	0.18	0.38	0.63
Weak instrument test	12.43	12.43	12.43

Notes: *, **, *** significant at 10, 5, 1% level; robust standard errors clustered at village level in parentheses.

Column 3 shows that health shocks also have a slightly significant effect on per capita health care expenditure, causing an increase of 31.5 percent. This implies that rural households have to cut down their non-healthcare consumption in response to income variation and unexpected healthcare cost. Our result is contrary to that of previous studies from Vietnam (Mitra et al., 2016; Thanh & Duong, 2017), Bangladesh (Islam & Maitra, 2012; Powell-Jackson & Hoque, 2012), and Indonesia (Gertler et al., 2009; Genoni, 2012; Sparrow et al., 2014) where these authors suggests that household consumption is fully insured against health shocks. There are two reasons that might explain our result. First, the difference may come from the way they capture the severity of illnesses. For example, Mitra et al. (2016) measure health shocks by "days of regular activity lost because of illness/injury" and "days in bed due to illness/injury" but the mean values of these indicators are less than two weeks and five days, respectively. In this regard, our result shares the view from Gertler & Gruber (2002) who distinguish between different degrees of illness and conclude that households are unable to protect their consumption against severe health impairments. Second, the endogeneity issue has been ignored in these previous studies. Ill health events are actually endogenous (Bound, 1991; Strauss & Thomas, 2006; Mohanan, 2013) but they are often treated as exogenous. This is common for research carried out in low- and middle-income countries where health shocks largely rely on self-reported health measures (Alam & Mahal, 2014). Even when an attempt has been made to overcome this problem, for example, by presenting health shocks as an index of specific categories of individual's physical functioning abilities (ADLs) (Gertler & Gruber, 2002), the measure still employs self-rated health and disability (Mohanan, 2013). In addition, ADLs are more relevant to capture the health of older population and it may underestimate the rural health situation (Genoni, 2012).

4.2 Effects of health shocks on over-indebtedness

As over-indebtedness is determined by the debt service to income ratio, it is likely that the impact of health shocks on over-indebtedness may go through two channels. On the one hand, indebted households may become over-indebted when their repayment capacity is in danger. Health shocks make this happen via lowering labour supply and then reducing household income. The size of income loss could be large enough to push households into financial vulnerability, especially in areas where the informal wage sector is the main source of household livelihoods. On the other hand, over-indebtedness could be a result of an escalation in household borrowings. This can occur if the healthcare expenditure becomes so burdensome to the household that traditional insurance mechanisms relying on income transfer over time (e.g. savings) or across spaces (e.g. remittances) are no longer effective. As a result, rural households have to rely on credit markets to smooth their consumption. Over-indebtedness would be more serious if households cover their financial deficit by informal loans as informal lenders request higher interest payments than formal institutions (Barslund & Tarp, 2008; Kislat, 2015; Nguyen, Thanh-Tung et al., 2020).

To verify the second channel, we continue to employ equation (10) to estimate the impact of health shocks on access to formal and informal credit. As borrowings from formal and informal sources can be substitutes and affect each other, two different models are estimated to control for them. Columns (1) and (2) in Table 5 present regression results without controlling for either formal or informal credit while Columns (3) and (4) do. Estimation results in Table 5 show that health shocks are responsible for a 12 percent increase in accessing informal credit. However, the effect of health shocks is not statistically significant with regard to accessing formal credit. A similar result is also found for the exposure to weather shocks (Columns 2 and 4). This finding is consistent with the result from Barslund & Tarp (2008) that informal loans in Vietnam are used for consumption smoothing while formal loans are entirely used for production and asset

accumulation. The result also supports the findings of previous studies from other developing countries such as India (Mohanan, 2013) and Mexico (Ambrosius & Cuecuecha, 2013) where taking up additional loans is an important mechanism to cope with health shocks.

We then go to the next step and look at the impacts of health shocks on different levels of household's over-indebtedness. We use different regression specifications to examine whether the state of over-indebtedness is due to health shocks or simply generated from simultaneous borrowings as found by Chichaibelu & Waibel (2017). The results are presented in Table 6. As shown in Table 6, health shocks significantly push households into a situation of over-indebtedness regardless of whether credit access is controlled for or not. More specifically, health shocks increase the probability of over-indebtedness by 7-7.7 percent (Columns 1-3). The coefficients are slightly lower (around four to five percent) but still positive and statistically significant when we control for both formal and informal credit (Columns 4-6). Although the magnitude of effects is small, it reveals that insuring consumption through borrowings can come at a cost in the long term, particularly when informal loans are largely taken. Going beyond health shocks, Table 6 illustrates whether shocks are also an important driver of over-indebtedness. The mechanism that weather shocks link households to over-indebtedness is quite similar as health shocks do. They cause a 24.3 percent loss in per capita farm income, a 28.1 percent reduction in per capita total income (Table 3), and induce households to borrow informal credits to smooth consumption (Table 5). Given these results, our study supports the notion that in developing countries shocks are external drivers of household's over-indebtedness (Schicks, 2013a; Gutiérrez-Nieto et al., 2017). We also reconfirm and supplement the existing evidence that captures this notion (e.g. Schicks, 2014; Chichaibelu & Waibel, 2018) by naming particular impact of health shocks and weather shocks. However, shocks are not the only factor that either causes over-indebtedness or a rise in informal borrowings. Financial exclusion is also an important driver (Gloukoviezoff, 2007; Koku, 2015).

Table 6: Impact of health shock on credit access

	(1) Formal credit	(2) Informal Credit	(3) Formal credit	(4) Informal Credit
Health shocks	0.014	0.121***	0.025	0.125***
	(0.034)	(0.030)	(0.033)	(0.029)
Formal credit				-0.047
				(0.031)
Informal credit			-0.031	
			(0.036)	
Health insurance	-0.060*	0.026	-0.047	0.028
	(0.031)	(0.034)	(0.030)	(0.031)
Remittances	0.058*	0.045	0.061**	0.055*
	(0.030)	(0.034)	(0.030)	(0.032)
Age	0.000	-0.002*	0.000	-0.002*
	(0.001)	(0.001)	(0.001)	(0.001)
Education	0.008***	-0.001	0.008***	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Household size	0.002	0.003	0.004	0.003
	(0.007)	(0.006)	(0.007)	(0.005)
Household labor	0.010	0.015**	0.007	0.016**
	(0.007)	(0.006)	(0.007)	(0.006)
Farm land (ha)	0.007	0.008	0.005	0.008
	(0.005)	(0.006)	(0.004)	(0.006)
Motorbike	-0.005	-0.010	-0.008	-0.013*
	(0.010)	(0.009)	(0.010)	(0.008)
Mobile phone	0.000	-0.006	-0.000	-0.006
	(0.006)	(0.005)	(0.006)	(0.005)
Livestock (TLU)	0.002***	-0.001*	0.002***	-0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
Village road quality	0.001	-0.015**	0.002	-0.015**
	(0.007)	(0.006)	(0.007)	(0.006)
Distance to town	-0.001	-0.001	-0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Weather shocks	0.002	0.032***	0.006	0.034***
	(0.012)	(0.011)	(0.011)	(0.010)
Year 2	0.070***	0.038**	0.071***	0.039***
	(0.015)	(0.015)	(0.014)	(0.014)
Year 3	-0.008	-0.025	-0.011	-0.025
	(0.019)	(0.018)	(0.018)	(0.018)
Year 4	0.007	0.054***	0.007	0.058***
	(0.022)	(0.019)	(0.020)	(0.019)
Number of observations	7304	7304	7304	7304
F-test	5.65	6.27	6.04	6.97
P-value	0.00	0.00	0.00	0.00
Under-identification test	0.00	0.00	0.00	0.00
Over-identification test	0.36	0.67	0.59	0.92
Weak instrument test	22.32	22.32	15.53	15.43

Notes: *, **, *** significant at 10, 5, 1% level; robust standard errors clustered at village level in parentheses

Table 7: Impact of health shocks on over-indebtedness

	(1) DSR=0.5	(2) DSR=0.4	(3) DSR=0.3	(4) DSR=0.5	(5) DSR=0.4	(6) DSR=0.3
Health shocks	0.069***	0.068***	0.077***	0.054**	0.045*	0.051*
	(0.025)	(0.026)	(0.028)	(0.022)	(0.024)	(0.026)
Formal credit				0.019	0.034	0.043*
				(0.020)	(0.022)	(0.023)
Informal credit				0.107***	0.102***	0.127***
				(0.020)	(0.023)	(0.022)
Health insurance	0.000	0.026	0.030	0.009	0.031	0.037
	(0.021)	(0.023)	(0.026)	(0.019)	(0.022)	(0.024)
Remittances	0.006	0.015	0.019	-0.009	0.001	0.012
	(0.021)	(0.024)	(0.025)	(0.018)	(0.021)	(0.023)
Age	-0.000	-0.000	-0.000	0.001	0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Education	0.001	0.001	0.001	0.001	-0.000	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Household size	-0.011**	-0.015***	-0.011**	-0.010**	-0.016***	-0.012***
	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)
Household labor	0.007	0.008	0.008	0.002	0.010**	0.010**
	(0.005)	(0.005)	(0.006)	(0.004)	(0.005)	(0.005)
Farm land (ha)	0.005	0.007*	0.007	-0.000	0.002	0.001
	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)
Motorbike	0.006	0.005	-0.001	0.005	0.006	-0.002
	(0.005)	(0.006)	(0.007)	(0.005)	(0.005)	(0.006)
Mobile phone	-0.002	-0.001	0.001	-0.002	-0.002	0.000
	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)
Livestock (TLU)	-0.002***	-0.002***	0.001**	-0.001***	-0.002***	0.002***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Village road quality	-0.009**	-0.008	-0.012**	-0.010***	-0.008*	-0.010**
	(0.004)	(0.005)	(0.006)	(0.004)	(0.004)	(0.005)
Distance to town	0.000	0.001	0.001	0.001	0.001	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Weather shocks	0.035***	0.047***	0.047***	0.029***	0.039***	0.037***
	(0.008)	(0.009)	(0.009)	(0.007)	(0.008)	(0.008)
Year 2	0.026**	0.045***	0.063***	0.025**	0.036***	0.053***
	(0.011)	(0.011)	(0.012)	(0.010)	(0.010)	(0.011)
Year 3	-0.010	-0.009	0.003	-0.004	-0.003	0.010
	(0.013)	(0.014)	(0.015)	(0.011)	(0.012)	(0.013)
Year 4	-0.005	0.004	0.018	-0.007	-0.001	0.021
	(0.014)	(0.015)	(0.016)	(0.012)	(0.013)	(0.014)
Number of observation	7304	7304	7304	7304	7304	7304
F-test	3.87	5.93	5.97	6.73	8.51	9.82
P-value	0.00	0.00	0.00	0.00	0.00	0.00
Under-identification test	0.00	0.00	0.00	0.00	0.00	0.00
Over-identification test	0.11	0.12	0.07	0.07	0.07	0.05
Weak instrument test	22.32	22.32	22.32	12.43	12.43	12.43

Notes: *, **, *** significant at 10, 5, 1% level; robust standard errors clustered at village level in parentheses

Rural households with limited access to formal credit have to cover their liquidity constraints by taking arrangements with informal lenders, thus making their debts unsecured and unmanageable. In Table 6, formal loans, for the most part do not show a statistical relationship with over-indebtedness. Meanwhile, having access to informal credit increases the probability of falling into over-indebtedness by 10-12 percent. This result is consistent with the common finding that informal credit market still plays an important role in the developing world (Collins, 2008; Barslund & Tarp, 2008; Kislat, 2015).

4.3 Impact of credit access on consumption smoothing

Morduch (1995) states that there are two mechanisms to smooth consumption: (i) smooth income to smooth consumption and (ii) smooth consumption directly. Access to credit, therefore, can be an *ex-ante* or *ex-post* health risk coping strategy. For example, households may borrow to smooth consumption through paying for a sudden increase in medical treatment (Nguyen et al., 2012). Alternatively, households may use credits to invest in farm and non-farm activities to generate income (Imai et al., 2010; Luan & Bauer, 2016) and thereby use this income to compensate for the cost of illness (Gertler et al., 2009; Islam & Maitra, 2012) or improving food consumption (Phan et al., 2019). To explore which mechanism is applied, we employ equation (2) to examine the particular role of formal and informal credit. The results are presented in Table 7. According to Table 7, the interaction terms between health shocks and formal credit (Columns 1 and 2), and between health shocks and informal credit (Columns 4 and 5) are significantly and positively associated with per capita total consumption and per capita non-healthcare consumption. That means that credit partly reduces the negative impact of health shocks on consumption. More specifically, households with access to formal credit have a 16 and 11 percent higher in per capita total consumption and per capita non-healthcare consumption than households without.

Table 8: Impact of credit access on smoothing consumption against health shocks

	(1) Total consumption	(2) Non-health consumption	(3) Health expenditure	(4) Total consumption	(5) Non-health consumption	(6) Health expenditure
Health shocks	-0.071**	-0.059*	0.342*	-0.086***	-0.092***	0.282*
	(0.031)	(0.030)	(0.208)	(0.031)	(0.029)	(0.168)
Formal credit	-0.043	-0.020	-0.124	-0.027	-0.012	-0.085
	(0.026)	(0.027)	(0.192)	(0.026)	(0.026)	(0.186)
Informal credit	0.040	0.027	0.623***	0.010	-0.002	0.756***
	(0.027)	(0.028)	(0.157)	(0.031)	(0.030)	(0.169)
Health insurance	0.072***	0.091***	0.365**	0.060**	0.077***	0.515***
	(0.026)	(0.027)	(0.162)	(0.027)	(0.028)	(0.160)
Remittances	0.059**	0.060**	0.122	0.049*	0.057**	0.160
	(0.029)	(0.028)	(0.135)	(0.028)	(0.027)	(0.136)
Health shocks* Formal credit	0.159***	0.110***	0.385			
	(0.038)	(0.037)	(0.253)			
Health shocks* informal credit				0.139***	0.089**	0.230
				(0.038)	(0.035)	(0.212)
Age	0.000	-0.001	0.014***	-0.000	-0.001	0.018***
	(0.001)	(0.001)	(0.005)	(0.001)	(0.001)	(0.005)
Education	0.009***	0.009***	0.028*	0.010***	0.009***	0.023
	(0.002)	(0.002)	(0.015)	(0.002)	(0.002)	(0.015)
Household size	-0.150***	-0.148***	-0.122***	-0.153***	-0.150***	-0.115***
	(0.005)	(0.005)	(0.035)	(0.005)	(0.005)	(0.033)
Household labor	0.001	-0.000	-0.006	0.002	0.000	-0.027
	(0.004)	(0.005)	(0.033)	(0.005)	(0.005)	(0.033)
Farm land (ha)	0.030***	0.029***	0.076**	0.032***	0.030***	0.083**
	(0.004)	(0.005)	(0.034)	(0.004)	(0.005)	(0.034)
Motorbike	0.110***	0.119***	-0.053	0.108***	0.118***	-0.044
	(0.007)	(0.007)	(0.039)	(0.007)	(0.007)	(0.037)
Mobile phone	0.045***	0.042***	0.135***	0.044***	0.041***	0.118***
	(0.004)	(0.004)	(0.027)	(0.004)	(0.004)	(0.027)
Livestock (TLU)	0.005***	0.005***	-0.006	0.005***	0.005***	-0.006
	(0.002)	(0.002)	(0.007)	(0.002)	(0.002)	(0.007)
Village road quality	-0.002	0.001	-0.108***	-0.002	0.002	-0.116***
	(0.005)	(0.006)	(0.032)	(0.005)	(0.005)	(0.033)
Distance to town	-0.000	-0.000	-0.026***	0.000	0.000	-0.027***
	(0.001)	(0.001)	(0.006)	(0.001)	(0.001)	(0.006)
Weather shocks	-0.017**	-0.011	0.025	-0.012	-0.007	0.035
	(0.009)	(0.009)	(0.049)	(0.009)	(0.009)	(0.051)
Year 2	0.091***	0.092***	-0.580***	0.093***	0.091***	-0.620***
	(0.012)	(0.012)	(0.095)	(0.013)	(0.012)	(0.094)
Year 3	0.230***	0.232***	-0.606***	0.243***	0.245***	-0.621***
	(0.016)	(0.016)	(0.099)	(0.016)	(0.016)	(0.097)
Year 4	0.344***	0.329***	0.181*	0.356***	0.338***	0.179*
	(0.018)	(0.017)	(0.096)	(0.018)	(0.017)	(0.094)
Number of observation	7304	7304	7304	7304	7304	7304
F-test	359.87	309.50	25.39	348.01	281.30	28.38
P-value	0.00	0.00	0.00	0.00	0.00	0.00
Under-identification test	0.00	0.00	0.00	0.00	0.00	0.00
Over-identification test	0.20	0.18	0.49	0.08	0.22	0.43
Weak instrument test	10.43	10.43	10.43	10.87	10.87	10.87

Notes: *, **, *** significant at 10, 5, 1% level; robust standard errors clustered at village level in parentheses

Similarly, access to informal loans facilitates households to increase their per capita total consumption and per capita non-healthcare consumption by 14 and nine percent, respectively. Our finding confirms those from previous studies from developing countries. For example, Islam & Maitra (2012) and Gertler et al. (2009) show that Bangladeshi and Indonesian households are able to mitigate the consequences of adverse health events when they have access to microcredit. Meanwhile, our result is contradictory to the finding from Thanh & Duong (2017) who report a negligible impact of credit access on insuring consumption against illness in Vietnam. Possibly, the difference may come from the way they include anticipated events such as pregnancy checks, insertion of intrauterine devices, and birth delivery into measurement of health shocks. In reality, households often have a sufficient financial plan for such expected events, either from self-finance or private transfer. Additionally, Thanh & Duong (2017) ignore the endogeneity concern in their model (i.e. health shocks and access to credit). Their estimation therefore can be biased.

4.4 Health insurance and financial protection

The main function of health insurance is to protect the insured from financial risks induced by substantial medical expense. If it does its job, insured households may not need to increase their borrowing or reduce their spending on other non-health consumption items in order to satisfy the increasing demand for health expenditure. We use equation (11) to examine this function of health insurance. Our outcome variables are per capita total consumption, per capita non-healthcare consumption, per capita healthcare expense, and different levels of over-indebtedness. The estimates are presented in Table 8.

With regard to consumption, interaction terms between health insurance and health shocks in columns (1) and (2) in Table 8 are significantly and positively associated with per capita total consumption and per capita non-healthcare consumption. More specifically, per capita total

consumption and non-healthcare consumption of insured households are nine and seven percent higher than uninsured households when exposed to health shocks. This implies that health insurance helps rural households partly to reduce the negative impact of health shocks on consumption. Our result reconfirms prior findings from Wagstaff & Pradhan (2005) and Bai & Wu (2014) who find that health insurance helps to prevent larger drops in non-healthcare consumption in Vietnam and China, respectively.

In terms of debt burden, columns (4)–(6) in Table 8 illustrate that the interaction term is negatively and significantly associated with the likelihood of over-indebtedness at all levels. The interaction coefficients show that the insured have a nine to 12 percent lower probability of falling into over-indebtedness than non-insured households. Evidently, health insurance, through mechanism of cost recovery helps insured households to depend less on borrowings, especially informal borrowings in response to severe illness.

Regarding healthcare expenditure, the interaction term in column (3) of Table 8 indicates that insured households spend 52.6 percent more on healthcare than non-insured ones when health shocks occur. This result is somewhat contradictory to the expectation that owning health insurance helps to reduce medical expense. However, similar situation is also found in other developing countries, for example in China (Wagstaff & Lindelow, 2008), Indonesia (Sparrow et al., 2013), and Peru (Bernal et al., 2017). There are two possible explanations for this. First, health insurance may cause higher medical expenses if the demand for health care is either especially elastic to the price or very sensitive to the reduction of risk and uncertainty (Wagstaff & Pradhan, 2005). Second, the healthcare expenditure includes other expenses than only cost of medical use and treatment services. Both these possibilities are existing in Vietnam.

Table 9: Impact of health insurance on consumption smoothing and over-indebtedness

	(1) Total consumption	(2) Non-health consumption	(3) Health expenditure	(4) DSR=0.5	(5) DSR=0.4	(6) DSR=0.3
Health shocks	-0.054**	-0.072***	0.196	0.083***	0.065***	0.069***
	(0.026)	(0.027)	(0.190)	(0.022)	(0.022)	(0.026)
Formal credit	-0.038	-0.030	-0.113	0.020	0.043*	0.054**
	(0.026)	(0.026)	(0.185)	(0.020)	(0.022)	(0.022)
Informal credit	0.039	0.031	0.664***	0.103***	0.104***	0.125***
	(0.027)	(0.027)	(0.159)	(0.020)	(0.022)	(0.021)
Health insurance	0.061**	0.083***	0.304*	0.015	0.030	0.037
	(0.027)	(0.027)	(0.168)	(0.020)	(0.022)	(0.025)
Remittances	0.063**	0.069**	0.220*	-0.008	0.006	0.012
	(0.028)	(0.028)	(0.133)	(0.017)	(0.020)	(0.023)
Health shocks* Health insurance	0.091***	0.067*	0.526**	-0.094***	-0.108***	-0.119***
	(0.034)	(0.035)	(0.226)	(0.027)	(0.029)	(0.031)
Age	0.000	-0.000	0.015***	-0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.005)	(0.001)	(0.001)	(0.001)
Education	-0.005**	-0.005**	0.015	-0.000	-0.001	-0.001
	(0.002)	(0.002)	(0.012)	(0.001)	(0.001)	(0.002)
Household size	-0.152***	-0.150***	-0.138***	-0.010**	-0.015***	-0.013***
	(0.005)	(0.005)	(0.036)	(0.004)	(0.004)	(0.004)
Household labor	0.009**	0.006	0.020	0.004	0.010**	0.010**
	(0.005)	(0.005)	(0.034)	(0.004)	(0.005)	(0.005)
Farm land (ha)	0.028***	0.028***	0.089***	-0.002	-0.001	-0.001
	(0.005)	(0.005)	(0.034)	(0.003)	(0.003)	(0.004)
Motorbike	0.119***	0.129***	-0.080**	0.004	0.003	-0.004
	(0.007)	(0.007)	(0.038)	(0.005)	(0.005)	(0.006)
Mobile phone	0.044***	0.041***	0.127***	-0.002	-0.001	-0.001
	(0.004)	(0.004)	(0.027)	(0.003)	(0.003)	(0.004)
Livestock (TLU)	0.004**	0.005***	-0.007	-0.001**	-0.002***	0.002***
	(0.002)	(0.002)	(0.007)	(0.000)	(0.000)	(0.000)
Village road quality	-0.005	-0.000	-0.117***	-0.010***	-0.008*	-0.009*
	(0.005)	(0.005)	(0.034)	(0.004)	(0.004)	(0.005)
Distance to town	-0.001	-0.001	-0.028***	0.001	0.001	0.001**
	(0.001)	(0.001)	(0.006)	(0.001)	(0.001)	(0.001)
Weather shocks	-0.015*	-0.010	0.102**	0.028***	0.038***	0.034***
	(0.009)	(0.009)	(0.049)	(0.007)	(0.008)	(0.008)
Year 2	0.095***	0.095***	-0.628***	0.025***	0.030***	0.049***
	(0.012)	(0.012)	(0.096)	(0.009)	(0.010)	(0.010)
Year 3	0.240***	0.237***	-0.585***	0.002	-0.002	0.009
	(0.016)	(0.016)	(0.097)	(0.012)	(0.012)	(0.013)
Year 4	0.344***	0.327***	0.199**	0.002	-0.000	0.019
	(0.018)	(0.017)	(0.097)	(0.012)	(0.013)	(0.013)
Number of observations	7304	7304	7304	7304	7304	7304
F-test	331.32	264.05	27.72	7.13	9.38	10.09
P-value	0.00	0.00	0.00	0.00	0.00	0.00
Under-identification test	0.00	0.00	0.00	0.00	0.00	0.00
Over-identification test	0.32	0.35	0.65	0.09	0.10	0.06
Weak instrument test	11.47	11.47	11.47	11.47	11.47	11.47

Notes: *, **, *** significant at 10, 5, 1% level; robust standard errors clustered at village level in parentheses

On the one hand, healthcare services are mainly provided by a public healthcare system that goes along with four administrative levels, from communal to district, provincial, and central (national) level. However, the quality and facilities of health care services at the two lowest level is low due to the lack of healthcare professionals and poor medical infrastructure (Somanathan et al., 2014). Patients with severe health problems prefer to go to provincial and central hospitals for taking medical consultancy and treatment, and thus making healthcare demand very high in such hospitals (Matsushima et al., 2020). Consequently, informal payment is commonly practiced in the overloaded hospitals to help patients jump the queues (Matsushima & Yamada, 2016).

On the other hand, hospital staff are also encouraged to over-service for additional income because their salary is coordinated with the hospitals' net revenues while prices for healthcare services are locked at regulated band (Matsushima & Yamada, 2016; Nguyen, Ha Thi Hong et al., 2017; Matsushima et al., 2020). As a result, healthcare expenditure does not only include treatment fee but also other related costs such as service charge for additional medicinal requirements, equipment, transportation, and informal payment for doctors (Nguyen, 2012; Matsushima et al., 2020).

It is also important to note that having health insurance has substantially increased household's healthcare utilization in Vietnam (Wagstaff & Pradhan, 2005; Nguyen, 2012; Nguyen & Wang, 2013; Palmer, 2014; Nguyen, 2016; Matsushima et al., 2020). Given their experience from more regular inpatient and outpatient visits and being covered for healthcare cost, the insured might be willing to pay more for using over-care services or taking better medical treatment and consultancy at higher-level hospitals[4]. As show in Appendix 3, 61 percent of insured households

[4] Following the Law on Health Insurance for people participating in either compulsory or voluntary health insurance, 80 percent of medical costs will be covered when taking medical consultancy and treatment at the

went to provincial hospitals for treatment while only 39 percent of the non-insured went there when exposed to health shocks. It is likely that the non-insured households hesitate to cover both medical and hidden charges, and thus select the less expensive one for treatment. This may prolong the duration of health recovery, and in turn have negative effects on consumption.

5. Conclusion

Adverse health events are the most common idiosyncratic shocks in human life. They affect the available resources for household consumption through reducing labour supply, decreasing earning income, and increasing medical cost. Dealing with health shocks is therefore not only dealing with health risk but also with financial risk. In low- and middle-income countries, households may use costly coping strategies such as selling productive assets, lowering education expenses, borrowing from moneylenders in response to health shocks due to the non-existing or incomplete financial market. In turn, these coping strategies may have negative consequences on household's economic opportunities in the future. Estimating the impact of health shocks is thus important for designing and promoting proper mitigating instruments. However, this is not a trivial task. Health shocks can have very different impacts depending on their length and severity.

In this paper, we examine the economic impacts of severe ill health events which were reported as major income shocks by rural households. In addition, we explores the mechanisms through which health shocks push households into over-indebtedness. Based on that, we investigate the role of credit and health insurance in mitigating the negative effects of health shocks. We employ the heteroscedasticity-based estimator to a four-wave balanced panel dataset in Vietnam to overcome the endogeneity issue. The results show that health shocks lead to a significant

insured's registered primary care establishment. If bypassing this first contacting points without referral from doctors, 60-70 percent of the cost at provincial hospitals and 40-50 percent at centre hospitals will be covered.

decline in off-farm income and a substantial increase in healthcare expenditure. These losses are then transmitted into consumption and make rural household unable to fully insure not only non-health consumption but also total consumption. In response to health shocks, households increase informal borrowings to smooth their consumption, which results in over-indebtedness. Getting access to formal credit and health insurance helps households to lower their decrease of non-health consumption. Moreover, health insurance can reduce the probability of being over-indebted.

As rural transformation is an ongoing process in developing countries, our study suggests that severe illnesses are an important income shock among rural households. This is especially true for those with family members being engaged in the informal off-farm sector. Having access to credit and insurance markets can be crucial ex-ante instruments for mitigating the short-term and long-term effects of these adverse health events. Therefore, it is essential to eliminate barriers to access formal credit in order to improve household's self-insurance capacity. Meanwhile, promoting healthcare and enhancing healthcare service provision at the local level should go together to bring more benefits to insured households and prevent them falling into financial hardship.

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Appendices

A1: Name and definition of the independent variables

Variable	Definition
Household level	
Age	Age of household (HH) head in years
Education	Highest number of school years of HH members
Household size	Number of HH nucleus members who stay in the HH for at least 180 days
Household labor	Number of HH nucleus members, aging from 15-65 years old
Farmland size	Total area of agricultural land of the household in ha
Motorbike	Number of motorbikes of household
Mobile	Number of active mobile used by household members
Formal credit	Dummy if HH has an access to formal credit sources in the last years (1 = yes)
Informal credit	Dummy if HH has an access to informal credit sources in the last years (1 = yes)
Livestock	Number of livestock owned by HH (in tropical livestock unit)
Remittances	Dummy if HH receives remittances from family members (1 = yes)
Health insurance	Dummy if HH has voluntary or compulsory health insurance (1 = yes)
Weather shock	Dummy if HH experienced weather shocks in the last years (1 = yes)
Village characteristics	
Road type	4=two-lane road; 3=single lane road; 2=all seasons dirt road; 1=dirt road, seasonally not viable
Distance to town	Distance from village to the district town in km
Year dummies	
Year 2	Dummy if the data wave is of 2010 (1 = yes)
Year 3	Dummy if the data wave is of 2013 (1 = yes)
Year 4	Dummy if the data wave is of 2016 (1 = yes)

A2: Impact of illnesses of less than 4 weeks on household consumption

	(1) Total consumption b/se	(2) Non-health consumption b/se	(3) Health expenditure b/se
Health shocks	0.063**	0.047	0.936***
	(0.032)	(0.034)	(0.198)
Formal credit	-0.040	-0.021	0.082
	(0.027)	(0.026)	(0.178)
Informal credit	0.039	0.022	0.639***
	(0.029)	(0.029)	(0.159)
Health insurance	0.060**	0.077***	0.448***
	(0.027)	(0.027)	(0.158)
Remittances	0.086***	0.070**	0.178
	(0.029)	(0.029)	(0.143)
Age	-0.001	-0.001	0.020***
	(0.001)	(0.001)	(0.005)
Education	0.010***	0.009***	0.028*
	(0.002)	(0.002)	(0.016)
Household size	-0.151***	-0.148***	-0.119***
	(0.005)	(0.005)	(0.033)
Household labor	0.000	-0.002	-0.018
	(0.005)	(0.005)	(0.033)
Farm land (ha)	0.028***	0.028***	0.098***
	(0.005)	(0.005)	(0.034)
Motorbike	0.108***	0.117***	-0.078**
	(0.007)	(0.007)	(0.038)
Mobile phone	0.043***	0.041***	0.141***
	(0.004)	(0.004)	(0.028)
Livestock (TLU)	0.004**	0.005***	-0.003
	(0.002)	(0.002)	(0.006)
Village road quality	-0.004	0.000	-0.103***
	(0.005)	(0.006)	(0.033)
Distance to town (km)	0.001	0.001	-0.028***
	(0.001)	(0.001)	(0.006)
Weather shocks	-0.022**	-0.017*	-0.007
	(0.009)	(0.009)	(0.047)
Year 2	0.095***	0.092***	-0.688***
	(0.012)	(0.012)	(0.095)
Year 3	0.245***	0.244***	-0.667***
	(0.017)	(0.017)	(0.097)
Year 4	0.350***	0.334***	0.098
	(0.018)	(0.018)	(0.100)
No. of observations	7304	7304	7304
F-test	358.83	301.66	32.58
P-value	0.00	0.00	0.00
Under-identification test	0.00	0.00	0.00
Over-identification test	0.27	0.45	0.56
Weak instrument test	12.41	12.41	12.41

A3: Measure and place for treatment among household with health shocks (%)

		All	With health insurance	Without health insurance
1.	Measures taken against illness			
	did nothing	8.7	7.9	9
	went to a government hospital	83.7	87.1	82.6
	went to a commune health centre	13.2	7.2	15.3
	went to a pharmacy	6.2	7.9	5.6
	went to a doctor	4.5	4.3	4.6
	went to health worker	0.4	0.7	0.2
	went to traditional healer	4.5	4.3	4.6
	went to private hospital	7.2	5.8	7.7
	Self-treatment	1.3	1.4	1.2
2.	Place to take treatment			
	Communal health centre	22.5	18.7	23.7
	District hospital	29.2	25.2	30.5
	Provincial hospital	44.4	61.2	38.7
	Abroad	0.2	0	0.3
	Number of observations	553	140	413

Chapter 4. Shocks, Agricultural Productivity and Natural Resource Extraction in Rural Southeast Asia

Abstract

Natural resources are depleting at an alarming rate, causing severe threats to the sustainable development in many developing countries. Given an ambiguous relationship between shocks, agricultural productivity, and natural resource extraction, we used a dataset of about 4200 rural households surveyed in four Southeast Asian countries (Cambodia, Laos, Thailand, and Vietnam) to investigate the impact of shocks and agricultural productivity on natural resource extraction by rural households. Our results show that weather shocks and market shocks force households to extract more natural resources. An increased agricultural productivity, however, discourages natural resource extraction. In addition, our results show that low education and low access to electricity are positively associated with natural resource extraction. We suggest that measures enhancing agricultural productivity should be prioritized, and more assistance and support to farmers for mitigating the severe effects of weather shocks and market shocks should be provided. Furthermore, accelerating farm mechanization, land defragmentation, rural electrification, supporting the development of communication systems and local markets, and promoting rural education should be encouraged.

Key words: shocks; agricultural productivity; natural resource extraction; Southeast Asia.

1. Introduction

Natural resource extraction is one of the major livelihood strategies of rural households in Southeast Asian countries (Nguyen et al., 2015; Völker and Waibel, 2010). It provides a wide range of products such as food, medicine, fuel, and construction materials for fulfilling households' subsistence needs and generating cash income. However, natural resource degradation is happening at an alarming rate in this region (Feng et al., 2021; Leung et al., 2020; Sodhi et al., 2010). From 1990 to 2010, the total forest area of Southeast Asia had experienced a drop of around 30 million ha (Stibig et al., 2014). It is expected that this region could lose three-quarters of its original forests and more than 40% of its biodiversity by the end of the 21st century (Sodhi et al., 2004). These losses will also cause long-lasting consequences for the future provision of natural resources and ecosystem services as many of these degraded ecosystems will not be able to fully recover (Lampert, 2019). Therefore, identifying the factors affecting households' decision to extract natural resources is essential to provide useful information for policymakers and practitioners to design effective programs for environmental conservation.

Another major livelihood strategy of rural households in developing countries is agricultural production. It is the main source of employment and income for at least 30% of the population in low- and middle-income countries (World Bank, 2020). Of this percentage, small-scale farmers make up the majority, approximately 80% of the farming population (Lowder et al., 2016). Their conventional farming methods often rely on using cows as draught power, indigenous seeds, simple equipment, and are highly dependent on weather conditions (Boonsrirat, 2014; Nguyen et al., 2020). Therefore, their productivity is relatively moderate and might not be able to ensure adequate food and sufficient income for farmers (Nguyen et al., 2018a). Consequently, other income-generating activities such as natural resource extraction are also needed (Walelign, 2017).

The relationship between agricultural production and natural resource extraction has been investigated by a few studies, but their results are mixed. On the one hand, some studies show that improving agricultural efficiency could discourage households from extracting natural resources as it makes farming more profitable, therefore, increasing the opportunity cost of extraction activities (Illukpitiya and Yanagida, 2010). In addition, raising agricultural productivity makes farmers wealthier, allowing them to substitute market goods for forest goods. On the other hand, it is argued that raising incomes from and returns on agricultural activities motivate farmers to convert forests to farmland (Faris, 1999; Phelps et al., 2013). In addition, an increase in returns on agricultural production could make rural households wealthier, enabling them to access modern technologies to accelerate extraction activities (Bierkamp et al., 2021). It is noted that due to many drivers (natural but also socio-economic factors) and their interactions, it is difficult to provide robust predictions.

Natural resources are argued to play an important role as safety nets to shocks[5] for rural farmers in developing countries (Angelsen et al., 2014). In these countries, farmers are often prone to several types of shocks such as floods, droughts, or market instability, and as formal insurance mechanisms are often limited, shocks might cause severe impacts on their welfare, pushing them into food insecurity and poverty. Under these circumstances, farmers might enhance natural resource extraction for foods and compensate for income losses due to shocks. A few studies have investigated the impact of shocks on natural resource extraction, but the results vary across study sites and types of shocks. For example, Völker and Waibel (2010) show that weather shocks and health shocks significantly motivate rural Vietnamese households to extract more natural resources. Wunder et al. (2014) show that covariate shocks significantly push

[5] Shocks are events that cause damages to households' well-being (Haider and Kumar, 2019) and include weather shocks (e.g. floods, droughts, and storms), health shocks (e.g. illness or death), and market shocks (e.g. increase in input price or decrease in output price).

households to extract more natural resources, whereas the impact of idiosyncratic health shocks is insignificant. McSweeney (2004) finds that households in Honduras tend to sell forest products in response to illness and crop shortfalls, but they are more likely to use loans to cope with weather shocks. Moreover, previous studies separately investigate either the impact of shocks on agricultural productivity (Isoto et al., 2017, Amare et al., 2018) or the impact of shocks on natural resource extraction (Takasaki et al., 2004, Völker and Waibel, 2010). None of the empirical studies have taken into account the effect of shocks on agricultural productivity and natural resource extraction simultaneously.

Against this background, our study aims to study the interrelationship between shocks, agricultural productivity, and natural resource extraction by using a large dataset collected from about 4200 rural households in Southeast Asia (Cambodia, Laos, Thailand, and Vietnam). These Southeast Asian countries are chosen as (i) they are rich in natural resources but among the major hotspots of natural resource degradation, (ii) they have a large share of the population working in the agricultural sector and relying on natural resource extraction, (iii) households in these countries are highly vulnerable to shocks. Our empirical analysis includes two main steps. First, we used ordinary least squares (OLS) models to study the impact of shocks (weather shocks, market shocks, and health shocks) on natural resource extraction. Second, we employed the heteroscedasticity-based instrumental variable approach to study the impact of agricultural productivity on natural resource extraction. Estimations were conducted for the whole sample as well as for each country. In addition, we also undertook additional econometric models and specifications to check the robustness of our estimations.

The rest of the paper is structured as follows. Section 2 describes the study design, including study sites, data sources, and methodologies. Section 3 presents the results. Section 4 discusses the findings and Section 5 concludes with policy implications.

2. Study Design

2.1 Study sites and data sources

Our analysis was conducted in rural areas in four Southeast Asian countries, including Cambodia, Laos, Thailand, and Vietnam. This region is endowed with diverse natural resources, but it is also a major hotspot of deforestation and natural degradation (Estoque et al., 2019; Sodhi et al., 2010, Song et al., 2018, Feng et al., 2021). With regard to the economic characteristics of the four surveyed countries, Thailand is the most developed one and is categorized as an upper-middle income country, while Vietnam is a lower-middle income one, and Laos and Cambodia are in the group of the least developed countries (United Nations, 2015). In addition, these countries are commonly characterized by a majority of people living in rural areas and by high dependence on agriculture and natural resources (Birthal et al., 2019; Do & Park, 2019). The shares of the workforce in the agricultural sector in Cambodia, Laos, Thailand, and Vietnam are approximately 40%, 70%, 30%, and 40%, respectively (Birthal et al., 2019). Furthermore, Southeast Asia is among the most vulnerable regions to climate risks with Vietnam, Thailand, Cambodia, and Laos being ranked at 9^{th}, 13^{th}, 19^{th}, and 89^{th} position during the period from 1998 to 2017 (Eckstein et al., 2019). These countries are highly exposed to different types of climate hazards including floods, droughts and storms. The frequency of droughts and floods is quite similar in these counties, but Vietnam is more exposed to storms due to its long coastline (Yusuf & Francisco, 2009). It is estimated that climate change will result in even more frequent and more severe extreme weather events in this region, causing a potential drop in rice yield by up to 50% by 2100 compared to 1990 levels (Prakash, 2018). This poses severe threats and challenges to food security for an increasing population of around 800 million by 2050 (an increase of about 20% from 2019) (Birthal et al., 2019; Vollset et al., 2020).

Our data were collected in 2013 in eight provinces in these four countries: Stung Treng in Cambodia; Savannakhet in Laos; and Dak Lak, Ha Tinh and Thua Thien Hue in Vietnam; Buriram, Nakhon Phanom and Ubon Ratchathani in Thailand (see Figure 1). These provinces were selected because of (i) a high incidence of poverty, (ii) high reliance on agriculture, and (iii) rich and diverse natural resources. In Thailand and Vietnam, the survey was conducted under the project "Impact of shocks on the vulnerability to poverty: Consequences for development of emerging Southeast Asian economies (FOR 756)" funded by the German Research Foundation (DFG)[6]. This project aims to generate a deeper understanding of vulnerability to poverty in rural areas of these rapidly emerging economies. Following the guidelines of the United Nations Department of Economic and Social Affairs (United Nations, 2005), the random sampling was undertaken based on a three-stage procedure (sub-district, villages and then households; see Povel (2015) and Nguyen et al. (2017) for detailed information of the survey). In the first stage, sub-districts (communes) were sampled with a probability corresponding to the number of households living in these sub-districts, taking into account the population density to ensure that both densely and less densely populated communes are adequately covered (Povel, 2015). Then, sampled villages within the chosen sub-districts were selected with a probability proportional to the size of the population. At the third stage, ten households in each sampled village were randomly chosen. For a generalization of our findings in the Lower Mekong Basin region, similar surveys were conducted in Laos and Cambodia. The surveys were carried out in collaboration with local partners (Cambodia Development Research Institute in Cambodia; University of Champasak in Laos; University of Ubon Ratchathani in Thailand, and Hue University of Agriculture and Forestry in Vietnam). All enumerators were carefully selected and intensively trained before the surveys took place. Each enumerator conducted face-to-face interviews (each of around two hours) at households'

[6] https://www.tvsep.de/overview-tvsep.html

homes. Collected data from each interview was checked in multiple steps (by another enumerator, team leaders, and data typists). In case of missing or implausible data, questionnaires were sent back to the responsible enumerators for correction, either by phone or by another visit to the household.

Figure 1. Map of studied sites in Cambodia, Laos, Thailand, and Vietnam

All information used in our study was collected from the survey with two instruments, namely household questionnaires (for household heads) and village questionnaires (for village heads). The village questionnaire captures villages' information on population, infrastructure, geography, and socioeconomic conditions. The household questionnaire includes about 1000 variables classified into different sections (i.e. demographics, agricultural production, shock, natural resource extraction, non-farm employment, consumption, remittances and financial transfers). There are two separate sections, one for natural resource extraction and the other for shocks faced by rural households during the last three years. The information on natural resource extraction encompasses a wide range of activities such as fishing, hunting, collecting, and logging, types of extracted products, extraction places, extraction costs (e.g. fuel, tools, and materials), and total outputs (quantity and monetary value). The shock section records all shocks that the household has experienced during the last three years, and then 11 questions are asked for each shock event regarding shock type, time of occurrence, which household member is affected, perceived severity, and total losses in income, consumption or assets. To prevent reporting biases, the enumerators were trained to clarify with the surveyed households that an event is only considered a shock when it causes damages and losses to household income, household assets or leads to extra expenditure. As our study mainly focuses on the impact of agricultural productivity on natural resources extraction, we excluded households not engaged in farming activities. Therefore, the final sample includes 4,213 households (507 from Laos, 503 from Cambodia, 1,578 from Thailand, and 1,625 from Vietnam).

2.2 Methodology

2.2.1 Impact of shocks on agricultural productivity

The first step of our empirical analysis was to estimate the impact of shocks and other household and village characteristics on agricultural productivity. The productivity is represented by two

indicators: crop yield (total crop output value per hectare) and crop income per hectare. Crop yield has a positive value for all farmers and was therefore transformed into the logarithmic form in order to reduce potential outliers in value. Meanwhile, as some surveyed households report negative farm income, we did not transform this indicator into the logarithmic form. We applied an OLS regression to estimate agricultural productivity as follows:

$$A_{iv} = \alpha + \beta S_{iv} + \delta H_{iv} + \vartheta V_v + \epsilon_{iv} \quad (1)$$

where A_{iv} denotes either the natural logarithm of crop yield or crop income per hectare of household i in village v. S_{iv} represents shocks that household i faced in the last three years. H_{iv} is the vector representing household characteristics. V_v is the vector capturing the village characteristics and ϵ is the error term. α is the constant. β, δ, and ϑ are parameters showing impacts of shocks, household characteristics and village characteristics on agricultural productivity. It is expected that households suffering from shocks (S) have $100\% * (e^{\beta} - 1)$ lower crop yield (A, in ln form) than those without shocks (S). All monetary variables are measured in 2005 Purchasing Power Parity dollar (2005 PPP$[7]). Shocks are categorized into three main groups, namely weather shocks (e.g. floods, droughts, and storms)[8], health shocks (e.g. illness or death), and market shocks (e.g. increase in input price or decrease in output price). Household characteristics include age of household head, household size, number of male laborers (age 16-60 years), share of literate members, land area, irrigated land area, share of rice-planted area, share of fruit-planted area, number of land plots, tractor value (in ln form),

[7] 2005 PPP$ is a unit of currency that has the same power to purchase a comparable amount of goods and services in the domestic market of the converted country as an U.S. dollar would buy in the United States in 2005. To convert monetary variables measured in local currencies to 2005 PPP$, we divided their values by purchasing power parity conversion factor (World Bank, 2008) and by consumer price index ratio of the respective countries between 2013 and 2005.

[8] In addition to using household survey data, an extreme weather event can be identified with weather data (either measured or simulated). A popular source of weather data for determining an extreme weather event can be found at: https://data.giss.nasa.gov/impacts/agmipcf/agmerra/. See Nguyen and Nguyen (2020) for a review of the advantages and disadvantages of using household survey data or weather data to identify weather shocks.

number of mobile phones and total asset value per capita (in ln form). Village characteristics are represented by the distance to the nearest market, share of households with access to electricity, a dummy of whether the village is located in mountain areas, and province dummies. The detailed definition and dimension of these dependent and independent variables are described in Appendix A1. In addition, we checked the variance inflation factor (VIF) values to detect potential multicollinearity, and the results indicate no serious concern of this issue (see Appendix A2).

2.2.2 Impact of agricultural productivity on natural resource extraction

In the second step, we identified the effects of agricultural productivity on natural resource extraction by estimating the following model:

$$E_{iv} = \gamma + \rho A_{iv} + \varphi S_{iv} + \tau H_{iv} + \theta V_v + \varepsilon_{iv} \quad (2)$$

where E_{iv} is the total output value of extracted products (in ln form) of household i in village v. A_{iv}, S_{iv}, H_{iv}, and V_v are defined as in Equation 1. γ is the constant. ρ, φ, τ and θ are parameters showing impacts of agricultural productivity, shocks, household characteristics and village characteristics on the total output value of extracted products. It is expected that an increase in crop yield (A, in ln form) by 1% would lead to ρ% increase in the extraction output (E, in ln form). Households suffering from shocks (S) have $100\% * (e^{\varphi} - 1)$ higher extraction output (E, in ln form) than those without shocks (S).

As crop yield is a dependent variable in Equation (1), it is endogenous in estimating natural resource extraction as in Equation (2). We addressed this issue by employing the heteroscedastic-based instrumental variable method proposed by Lewbel (2012). This method allows us to generate internal instrumental variables (IVs). These IVs for A_i in estimating natural resource extraction in Equation (2) are constructed as: $\left[z_i^{'} - E(z_i^{'})\right]\hat{\xi}_i$. With ξ and z are

the residuals and exogenous variables in Equation 1, respectively. IVs are uncorrelated with ε_i in Equation (2) as it is assumed that $Cov(z_i', \varepsilon_i) = Cov(z_i', \xi_i) = Cov(z_i', \varepsilon_i \xi_i) = 0$. Meanwhile, due to the existence of heteroscedasticity ($Cov(z_i', \xi_i^2) \neq 0$), IVs are correlated with A_i through ξ_i. In addition, as Lewbel (2012) suggests, we used an additional external instrument to improve efficiency of this approach by employing the average crop yield per household in the village. To ensure the validity of our estimation, a number of post-estimation tests for underidentification, overidentification and weak instruments were conducted; the results of these tests confirmed the validity of our model (see Tables 3 and 4). In addition, we also checked the VIF values to detect potential multicollinearity, and the results do not show that problem (see Appendix A3). Moreover, as robustness checks, we also examined the impact of crop income per hectare on natural resource extraction and these results are highly consistent with the estimation results of Equation 2.

Another concern is that since we employed both household and village variables, they might not be independent. Thus, we performed two additional models: the first one with only household variables, and the second one is a mixed-effects model. The results of these models, as shown in Appendices (A8-A15), are consistent with those from our original model.

3. Results

3.1 Data description

Table 1 illustrates household and village characteristics by countries. With respect to demographic characteristics, households in Cambodia and Laos have larger household sizes, younger household heads, and lower literacy rates than in Thailand and Vietnam. On average, more than 80% of the sampled rural population in Thailand and Vietnam can read and write, whereas these figures in Cambodia and Laos are less than 60%. In addition, sampled households

in Thailand appear to be better off with a total asset value per capita of more than 2,000 PPP$. The total asset value per capita of households in Vietnam is only around 900 PPP$, but this is still higher than that of households in Cambodia and Laos. With regard to land and farm characteristics, households in Vietnam have the smallest land area, but the highest number of land plots. This is due to the agrarian land allocation undertaken at the beginning of the reform process known as *Doi Moi* in Vietnam (Huy et al., 2019). However, irrigation systems are more accessible in Vietnam than in the other countries. In particular, the irrigated land area is around 0.5 ha in Vietnam, accounting for around 50% of total land area that a household owns, whereas the figure in the other countries is less than 20%. This is in line with Birthal et al. (2019) who show that irrigation is limited to less than 20% of the cropland in most Southeast Asian countries, whereas in Vietnam more than 40% of the cropland is irrigated. This might explain why the total value of crop output per hectare is the highest in Vietnam. The average value of the crop yield in Vietnam is more than 4,700 PPP$ per hectare, whereas these figures in Thailand, Cambodia, and Laos are approximately 3,000 PPP$, 1,800 PPP$ and 1,000 PPP$, respectively. The higher yield in Vietnam could be explained by a large share of land used for industrial crops (around 25%) such as pepper, coffee as well as the intensive use of fertilizers and other agro-chemicals. For natural resource extraction, households in Laos and Cambodia are more involved in extraction activities. More specifically, more than 80% of the surveyed households in Laos and Cambodia participate in extraction activities, whereas these figures in Thailand and Vietnam are less than 50%. With regard to village characteristics, infrastructure in rural villages in Vietnam appears more developed than in Laos and Cambodia. Almost all farmers in Vietnam and Thailand have access to the national electricity grids. Meanwhile, the share of farmers having access to electricity in Laos and Cambodia is 60% and 20%, respectively. The average distance to the nearest market in Vietnam is less than 5 km, whereas it is more than 25 km in Cambodia.

Table 1. Household and village characteristics

	Whole Sample	Cambodia	Laos	Thailand	Vietnam
Household characteristics					
Age of head	53.63	44.8	48.89	58.76	52.87
(years)	(13.68)	(13.97)	(13.36)	(12.2)	(12.94)
Share of literate members	78.36	51.71	58.47	87.48	83.96
(%)	(26.91)	(30.41)	(31.66)	(18.77)	(21.96)
Household size	4.42	5.25	5.99	4.02	4.07
(numbers)	(1.97)	(1.93)	(2.46)	(1.67)	(1.74)
Male members	2.17	2.68	3.01	1.93	1.98
(%)	(1.3)	(1.39)	(1.63)	(1.13)	(1.14)
Total assets per capita	1411	503	759	2460	876
(2005 PPP$)	(3431)	(787)	(1234)	(5114)	(1649)
Tractor_value	1112	853	1531	1966	233
(2005 PPP$)	(4086)	(1679)	(1622)	(6376)	(753)
Mobile phones	1.86	1.17	1.26	2.12	2
(numbers)	(1.43)	(1.2)	(1.27)	(1.41)	(1.45)
Land area	1.87	3.04	2.24	2.29	0.99
(ha)	(2.12)	(3.02)	(1.89)	(2.21)	(1.24)
Irrigated land area	0.3	0.26	0.07	0.14	0.53
(ha)	(0.78)	(0.96)	(0.51)	(0.68)	(0.81)
No. of land plots	3.61	2.69	2.2	3.35	4.57
(numbers)	(1.95)	(0.85)	(0.48)	(1.6)	(2.29)
Share of rice-planted area	62.19	47.36	55.79	83.75	47.84
(%)	(41.39)	(44.96)	(44.65)	(30.27)	(39.62)
Share of fruit-planted area	6.17	23.98	7.01	2.65	3.81
(%)	(21.27)	(40.34)	(21.59)	(13.86)	(14.93)
Share of vegetable-	6.62	11.57	28.94	1.49	3.11
planted area (%)	(21.55)	(29.04)	(39.37)	(9.4)	(13.2)
Share of industrial crop-	11.87	0.29	0.58	5.36	25.31
planted area (%)	(27.96)	(4.5)	(5.66)	(17.61)	(37.51)
Crop income per ha	2375	1763	927	1911	3467
(2005 PPP$)	(3935)	(3316)	(1661)	(3468)	(4695)
Crop yield per ha	3301	1882	1132	2957	4751
(2005 PPP$)	(4389)	(3447)	(1719)	(3529)	(5381)
Extracting natural resource	55.49	81.91	84.22	48.54	45.11
(%)	(49.7)	(38.53)	(36.49)	(49.99)	(49.78)
Extraction income	387.79	1876	664.91	85.28	134.38
(2005 PPP$)	(1542)	(3853)	(1015.85)	(263.93)	(571.08)
Village characteristics					
Share of households having electricity	84.67	20.43	64.46	98.52	97.42
(%)	(33.08)	(32.71)	(42.61)	(7.73)	(11.38)
istance to market	9.51	26.96	14.63	8.88	3.12
(km)	(14.03)	(25.54)	(16.49)	(7.77)	(4.69)
Share of households in mountain regions	25.4	22.47	5.72	8.87	48.49
(%)	(43.53)	(41.78)	(23.25)	(28.44)	(49.99)
No. of households	**4213**	**503**	**507**	**1578**	**1625**

Standard deviations in parentheses, ha: hectare, 2005 PPP$: 2005 purchasing power parity.

Table 2. Descriptive statistics of extraction activities of rural households

	Whole sample	Cambodia	Laos	Thailand	Vietnam
Extracting places					
water (e.g. rivers, lakes)	31.79	35.59	34.01	40.4	10.21
(%)	(46.57)	(47.9)	(47.39)	(49.09)	(30.3)
forest and other lands	68.21	64.41	66	59.59	89.79
(%)	(89.86)	(69.19)	(83.34)	(85.2)	(97.12)
distance to extracting places	3.03	3.23	1.72	3.47	3.92
(km)	(6.98)	(6.91)	(3.26)	(5.82)	(11.17)
Type of activities					
Fishing	31.08	36.79	33.74	38.24	9.1
(%)	(46.29)	(48.25)	(47.3)	(48.61)	(28.78)
Hunting	7.44	7.53	14.37	3.81	3.57
(%)	(26.24)	(26.41)	(35.1)	(19.15)	(18.56)
Collecting	48.8	45.63	47.94	51.38	49.32
(%)	(49.99)	(49.84)	(49.98)	(50)	(50.03)
Logging	12.66	10.04	3.94	6.5	38.01
(%)	(33.26)	(30.07)	(19.47)	(24.66)	(48.57)
Output value and uses					
Total extraction value	385.77	1030.27	295.45	98.99	258.7
(2005 PPP$)	(1457.2)	(2864.13)	(559.58)	(242.46)	(769.03)
Value for sales	215.25	667.79	147.89	23.12	119.13
(2005 PPP$)	(1321.3)	(2651.6)	(510.14)	(139.13)	(669.14)
Value for consumption	170.33	363.73	148.75	75.86	139.56
(2005 PPP$)	(356.78)	(624.55)	(215.78)	(176.87)	(215.01)
No. of activities	**4209**	**916**	**1141**	**1339**	**813**

Standard deviations in parentheses, ha: hectare, 2005 PPP$: 2005 purchasing power parity.

Table 2 provides detailed information of extraction activities, including extraction locations (e.g. forests, rivers), types of extraction activities (e.g. fishing, logging), output value and the use of extracted products (e.g. for consumption or for cash income). Generally, forests are the most common extraction place in all surveyed countries with more than 60% of all extraction activities being undertaken. The distance to extraction places is farthest in Vietnam (approximately 4 km), and shortest in Laos (about 2 km). Meanwhile, the average distance to extraction places in Cambodia and Thailand is around 3 km. For types of extraction activities, collecting non-timber forest products is the most common in all sampled countries. Fishing is the second most common extraction activity in Cambodia, Laos, and Thailand, whereas logging is the second most common in Vietnam. The average output value of extraction activities is

highest in Cambodia with slightly more than 1,000 PPP$ and it is mainly used for sale. The average output value of extracted products is lowest in Thailand amounting to around 100 PPP$ and mainly for home consumption. The average value of extracted products in Laos and Vietnam is nearly 300 PPP$ with around half of this for home consumption and the other half for sale.

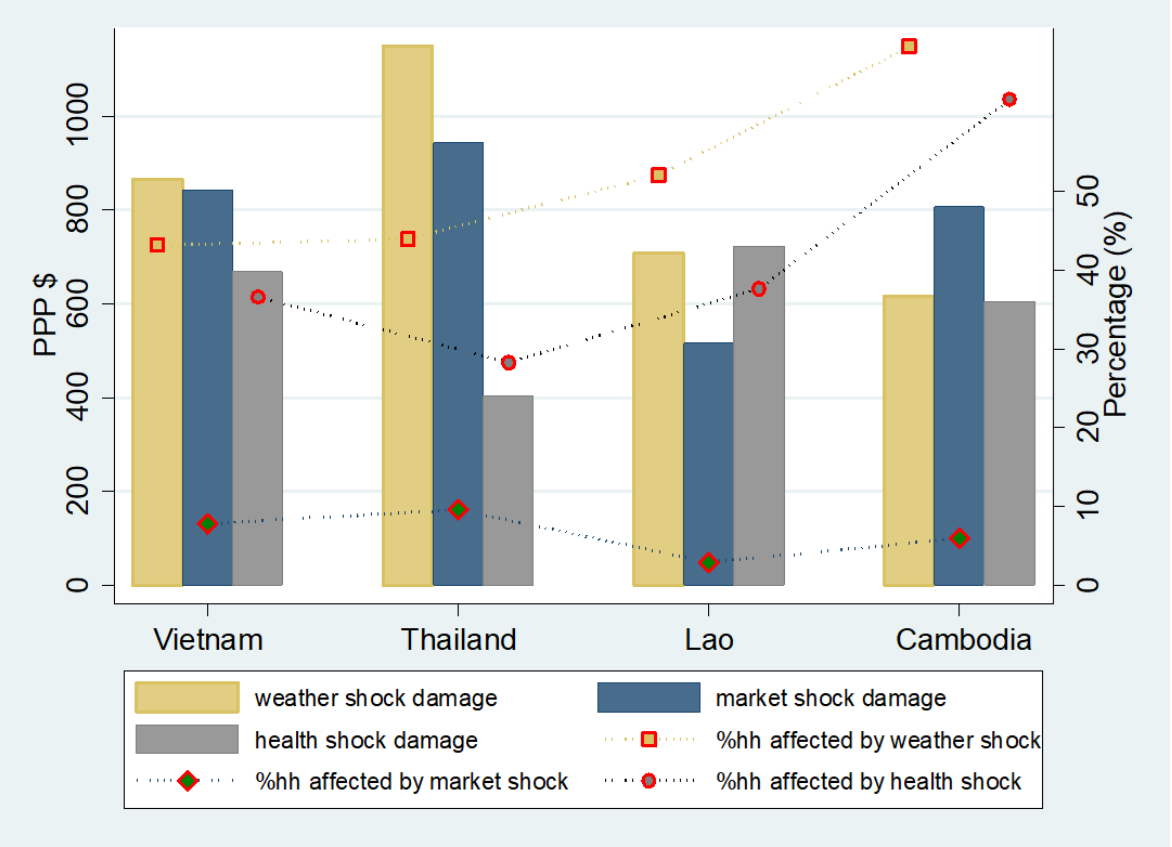

Figure 2. Percentage of affected households and average damages of shocks

Figure 2 presents the shares of affected households and the average damages and losses of shocks per affected household in the last three years. The line charts show that weather shocks are the most common, affecting more than 40% of the households in all surveyed countries. Meanwhile, the share of households affected by health shocks is more than 30%. Market shocks are less common, affecting less than 10% of the households in all surveyed countries. Comparing the prevalence and severity of shocks between countries, weather shocks and health

shocks are more common in Cambodia, whereas market shocks affect a larger share of households in Vietnam and Thailand. Weather shocks affect around 60% of the households in Cambodia, and 40-50% of the households in the other countries. These countries are reported as among the most vulnerable regions to climate risks such as floods, droughts and storms (Eckstein et al., 2019; Yusuf & Francisco, 2009).

The share of households affected by health shocks in Cambodia is around 55%, whereas this figure in the other countries is between 30% and 40%. As these studied countries are low- and middle-income countries in the tropical regions, rural households are highly exposed to different types of diseases such as malaria, cholera, dengue or parasitic diseases. In addition, households in these countries also face a lack of access to sanitation and hygiene, consequently posing them at high risk of waterborne diseases such as diarrhea or cholera. The World Bank reports that in 2013 only 47% of the Cambodian population had basic sanitation services (World Bank, 2013a). These figures in Laos, Vietnam and Thailand were 64%, 77%, and 96%, respectively. Furthermore, as farming is intensive and farm mechanization in these countries is limited, farmers often have to work intensively in the field and are highly exposed to pesticides and other toxic chemicals. Moreover, a large share of the population in Cambodia and Laos suffers from food insecurity and undernutrition (World Bank, 2013b, c). Mitra et al. (2016) show that nearly 20% of the sampled households in Vietnam have a member in bed due to illness/injury for at least one day and more than 40% of the sampled households have a member unable to carry out regular activities for at least one day. Wagstaff and Lindelow (2014) show that more than 30% of the sampled households in Laos suffer from health shocks. Meessen et al. (2011) show that 40% of the sampled individuals in Cambodia suffer from illnesses.

Market shocks affect around 10% of all households in Vietnam and Thailand, whereas less than 5% of the households in Cambodia and Laos are affected by market shocks. With respect to the damages and losses due to shocks, the bar charts show that weather shocks are the most severe

shocks to households in Thailand and Vietnam with an average damage of around 1,100 PPP$ and 900 PPP$, respectively. In Cambodia, the most severe ones are market shocks, causing an average damage of around 800 PPP$, whereas an average damage of health shocks and weather shocks in this country amounts to around 600$. In contrast, health and weather shocks are more severe in Laos, causing an average damage of around 700 PPP$, whereas the average damage of market shocks in this country is around 500$.

3.2 Impact of shocks on agricultural productivity

Table 3 shows the estimation of the effects of shocks. Column 1 shows the impact on crop yield (in ln form) while column 2 shows the impact on crop income. Models' summary statistics and diagnostics parameters are presented in the lower section of Table 1 with the p-value of the Wald chi^2 being statistically significant at the 1% level. Our findings show that weather shocks significantly reduce crop yield and crop income per ha. Crop yield of households with weather shocks are 15% lower than those without weather shocks.

In Table 4, we also disentangle the impact of shocks by countries. The incidence of weather shocks is negatively associated with crop yield and crop income per ha in all countries, although this impact is not statistically significant in Laos. Weather shocks are shown to decrease crop yield of households in Cambodia, Thailand, and Vietnam on average by 16%, 18% and 7%, respectively. With regard to other household and village characteristics (see Table 3 for the whole sample and Appendices 4 and 5 for each country), land area is negatively and significantly correlated with crop yield, whereas the impact of the square of land area is positively significant for all samples. This indicates the non-linear effect of land area on land productivity. Education is also shown to positively affect agricultural productivity in all countries, although the impact in Laos is insignificant.Our findings also show that the impact of irrigated land area on crop yield and crop income is positive and significant for the whole

sample and Vietnam. Meanwhile, the number of land plots, an indicator of land fragmentation, is negatively associated with crop income per hectare for the whole sample, Vietnam, and Cambodia. Mobile phones and tractors are shown to positively affect crop yield or crop income per hectare for the whole sample, Vietnam, and Laos. With regard to village characteristics, electricity access is found to have positive impacts on agricultural productivity in Cambodia and Laos. In addition, our results show that distance to markets is negatively associated with agricultural productivity for the whole sample and Vietnam. Moreover, Vietnamese and Thai households living in mountain regions are shown to have a lower crop yield than the others.

Table 3: Impact of shocks on agricultural productivity

	OLS models			
	Crop yield (in ln) (1)		**Crop income per ha (2)**	
weather shock	-0.139***	(0.026)	-590.786***	(120.622)
health shock	-0.011	(0.027)	-183.990	(120.646)
market shock	0.064	(0.048)	115.401	(259.143)
age head	0.002**	(0.001)	1.327	(4.563)
share of literate members	0.212***	(0.060)	482.253*	(273.153)
household size	0.008	(0.010)	-39.362	(49.583)
male members	-0.011	(0.015)	70.560	(58.470)
total asset value per capita (ln)	0.044***	(0.012)	71.714	(52.861)
tractor value (ln)	0.017***	(0.004)	5.408	(19.146)
mobile phone	0.031***	(0.010)	117.339**	(47.562)
land area	-0.136***	(0.014)	-364.068***	(55.455)
land area squared	0.004***	(0.001)	10.783***	(2.888)
irrigated land area	0.084***	(0.021)	284.282***	(88.247)
no of land plots	-0.003	(0.007)	-145.184***	(36.265)
share of rice-planted land	-0.335***	(0.041)	-2277.902***	(240.816)
(village) distance to market	-0.001	(0.001)	-4.494	(3.785)
(village) electricity	0.199***	(0.069)	595.916**	(267.158)
(village) mountain	-0.148***	(0.033)	-288.552*	(165.598)
Constant	7.406***	(0.139)	4086.740***	(679.304)
province dummies		yes		yes
No of observations		4213		4213
R^2		0.350		0.133
Adjusted R^2		0.346		0.128
P-value		0.000		0.000

Robust standard errors in parentheses; *** p<0.01, **p<0.05, * p<0.1

Table 4. Impact of shocks on agricultural productivity by countries

	OLS models			
	Cambodia	**Laos**	**Thailand**	**Vietnam**
	(1)	**(2)**	**(3)**	**(4)**
Panel A: Impact of shocks on crop yield (ln)				
weather shock	-0.149*	-0.059	-0.166***	-0.072*
	(0.088)	(0.070)	(0.038)	(0.041)
health shock	0.022	0.107	-0.025	-0.009
	(0.080)	(0.075)	(0.045)	(0.041)
market shock	0.218	0.071	-0.013	0.114
	(0.185)	(0.220)	(0.070)	(0.075)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
R^2	0.161	0.166	0.113	0.239
Adjusted R^2	0.130	0.135	0.102	0.229
P-value	0.000	0.000	0.000	0.000
Panel B: Impact of shocks on crop income per hectare				
weather shock	-1013.991***	-113.881	-631.415***	-372.531*
	(328.189)	(107.430)	(200.875)	(218.288)
health shock	267.985	-40.951	-182.516	-191.524
	(329.819)	(166.958)	(185.599)	(228.183)
market shock	1118.417	170.295	-98.264	134.122
	(1374.893)	(438.462)	(297.768)	(469.259)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
R^2	0.201	0.088	0.104	0.109
Adjusted R^2	0.171	0.055	0.093	0.098
P-value	0.000	0.000	0.000	0.000

Robust standard errors in parentheses; *** p<0.01, **p<0.05, * p<0.1

3.3 Impact of agricultural productivity on natural resource extraction

Table 5 presents the estimation of the total extraction output value. Column 1 shows the impact of crop yield on the total extraction output value, whereas the impact on crop income is in column 2. The models' summary statistics and diagnostics parameters, presented in the lower

section of the table, show that all tests for overidentification, underidentification and weak instruments meet statistical requirements, confirming the validity and relevance of our models.

Table 5. Impact of agricultural productivity on natural resource extraction

	Heteroscedasticity-Based Instrument			
	Extraction output value (ln) (1)		Extraction output value (ln) (2)	
crop yield (ln)	-0.25653***	(0.07449)		-
crop income per hectare	-		-0.00003***	(0.00001)
weather shock	0.38943***	(0.07679)	0.41787***	(0.07573)
health shock	-0.15839**	(0.07535)	-0.16402**	(0.07524)
market shock	0.31056**	(0.13926)	0.27288**	(0.13897)
age head	-0.01587***	(0.00283)	-0.01589***	(0.00282)
share of literate	-0.64603***	(0.16341)	-0.70862***	(0.16217)
household size	0.04128	(0.03092)	0.03986	(0.03083)
male members	0.10776**	(0.04442)	0.10704**	(0.04437)
total asset value per capita (ln)	-0.18136***	(0.03323)	-0.18869***	(0.03308)
tractor value (ln)	0.07428***	(0.01274)	0.06914***	(0.01267)
mobile phone	-0.07876***	(0.02962)	-0.08198***	(0.02951)
land area	-0.03404	(0.03805)	-0.01666	(0.03625)
land area squared	-0.00146	(0.00156)	-0.00159	(0.00147)
irrigated land	-0.00095	(0.05287)	-0.01349	(0.05213)
no of land plots	0.00978	(0.02175)	0.00577	(0.02171)
share of rice-planted land	-0.35265***	(0.10783)	-0.33359***	(0.10662)
(village) distance to market	0.00603**	(0.00269)	0.00573**	(0.00269)
(village) electricity	-0.45172**	(0.19471)	-0.47690**	(0.19481)
(village) mountain	0.33590***	(0.09249)	0.36725***	(0.09140)
constant	6.86579***	(0.66850)	5.08192***	(0.36624)
province dummies	yes		yes	
No of observations		4213		4213
R^2		0.355		0.357
Adjusted R^2		0.351		0.353
P-value		0.000		0.000
Underidentification		0.000		0.000
Overidentification		0.859		0.126
Weak identification		65.296		136.987

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors in parentheses; the underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis of all instruments being valid. For weak identification, Kleibergen-Paap rk Wald F statistics is reported.

Our results show that both crop income per hectare and crop yield are significantly and negatively associated with total extraction output. This indicates that enhancing agricultural productivity will discourage farmers from natural resource extraction. A 10% increase in crop yield would lead to a decrease in the extraction output of 2.6%. Regarding the impact of shocks on natural resource extraction, weather shocks and market shocks are significantly and negatively associated with the extraction output. Suffering from weather shocks and market shocks will increase the extraction output value by 48% and 36%, respectively. Meanwhile, suffering from health shocks reduces the extraction output by 15%.

Table 6 presents the estimations of total extraction output by country. Panel A shows the impact of crop yield on the total extraction output, whereas the impact of crop income is in panel B. The estimations for Cambodia, Laos, Vietnam, and Thailand are in columns 1, 2, 3, and 4, respectively. Our results show that enhancing crop yield or crop income per ha could significantly reduce the value of extraction output in all countries. Increasing crop yield by 10% would lead to a decrease in the extraction output of households in Cambodia, Laos, Thailand, and Vietnam by 3.5%, 0.7%, 2.3%, and 1%, respectively. With respect to shocks, our results show that the incidence of weather shocks is positively associated with the value of extraction output in all surveyed countries, although the impact of weather shocks in Thailand is statistically insignificant. Weather shocks are shown to increase the extraction output of households in Cambodia, Laos, and Vietnam. Market shocks are shown to increase the extraction output of households in Thailand. Health shocks are shown to reduce the extraction output of households in Laos and Thailand.

With regard to other household and village characteristics (see Table 5 for the whole sample and Appendices 6 and 7 for each country), better-off households (those with a higher value of total assets per capita) and better-educated households appear to have a lower value of

extraction output. In particular, education is negatively associated with the value of extraction output for the whole sample and for Cambodia, Laos and Vietnam.

Table 6. Impact of agricultural productivity on natural resource extraction by countries

	Heteroscedasticity-Based Instrument			
	Extraction output value (ln)			
	Cambodia (1)	**Laos (2)**	**Thailand (3)**	**Vietnam (4)**
Panel A: The impact of crop yields				
crop yield (ln)	-0.34740**	-0.07444	-0.22996**	-0.10572
	(0.17619)	(0.18632)	(0.11720)	(0.11202)
weather shock	0.79583***	0.36835*	0.10855	0.38424***
	(0.28879)	(0.19940)	(0.12128)	(0.11288)
health shock	-0.17573	-0.45904**	-0.21421*	-0.09543
	(0.24274)	(0.19053)	(0.12321)	(0.11188)
market shock	0.11113	-0.48134	0.67574***	0.24537
	(0.43845)	(0.64059)	(0.19575)	(0.21721)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
R^2	0.138	0.181	0.083	0.254
Adjusted R^2	0.104	0.149	0.070	0.244
P-value	0.000	0.000	0.000	0.000
Underidentification	0.000	0.000	0.000	0.000
Overidentification	0.527	0.211	0.740	0.195
Weak identification	23.810	15.705	41.455	30.393
Panel B: The impact of crop income				
crop income per hectare	-0.00009***	-0.00015***	-0.00004**	-0.00003**
	(0.00003)	(0.00002)	(0.00002)	(0.00001)
weather shock	0.77334***	0.35476*	0.13614	0.38417***
	(0.28681)	(0.19685)	(0.11936)	(0.11187)
health shock	-0.11098	-0.44104**	-0.20602*	-0.08859
	(0.23884)	(0.19216)	(0.12258)	(0.11112)
market shock	0.12583	-0.69307	0.62870***	0.22213
	(0.41762)	(0.64585)	(0.19733)	(0.21755)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
R^2	0.147	0.184	0.087	0.254
Adjusted R^2	0.113	0.152	0.075	0.244
P-value	0.000	0.000	0.000	0.000
Underidentification	0.037	0.043	0.000	0.000
Overidentification	0.627	0.068	0.712	0.106
Weak identification	194.187	952.641	140.986	37.098

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors in parentheses; the underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis of all instruments being valid. For weak identification, Kleibergen-Paap rk Wald F statistics is reported.

The total asset value per capita is negatively correlated with the value of extraction output for the whole sample and for Vietnam and Thailand. Owning mobile phones is shown to demotivate households from extracting natural resources for the whole sample, Laos and Vietnam.

With regard to demographic characteristics, the age of household heads is positively associated with natural resource extraction for the whole sample and Laos, Thailand and Vietnam. The number of male members positively affects the value of extraction output for the whole sample and for Vietnam. With regard to village characteristics, the distance to markets is positively correlated with natural resource extraction for the whole sample, Cambodia and Vietnam. Meanwhile, having access to electricity is shown to negatively affect the extraction of rural households in Cambodia and Laos.

4. Discussion

Our estimation results show a significant and negative impact of weather shocks on agricultural productivity. The severe impact of weather shocks could be because households are less able to cope with extreme weather events as these shocks affect a large number of people in the region, causing severe damages to houses, croplands, and infrastructure, disrupting severely transportation and communication across regions, and limiting risk-sharing mechanisms as everybody in the community is being affected (Nguyen et al., 2020; Kurosaki, 2015; de Silva and Kawasaki, 2018). Moreover, weather shocks directly cause crop losses and failure. Figure 2 shows that weather shocks are most common in our study sites and cause the most severe damages to households. By countries, our findings show that weather shocks are negatively associated with crop yield and crop income in all countries, although the impact is not statistically significant in Laos. The insignificant impact in Laos could be because the average damages and losses due to weather shocks in Laos are less severe than in Vietnam and Thailand

(see Figure 2). This is also consistent with Eckstein et al. (2019), who show that Laos is generally less vulnerable to climate risks than Vietnam, Thailand or Cambodia.

Our results also show that education, tractor value, mobile phones, and irrigation land area are positively and significantly associated with crop yield. This makes sense as households with higher education levels might have better abilities to manage information, and owing mobile phones could facilitate the exchange of farm-related information. These results are also consistent with Ebers et al. (2017) and Sauer et al. (2015), who show that promoting farm mechanization and rural education could significantly reduce farm inefficiency. Our findings also show that land fragmentation negatively affects crop yield. This is particularly true in Vietnam where cropland is highly fragmented being a major cause of agricultural inefficiency (Huy et al., 2019). Land fragmentation may inhibit the adoption of machinery, and increase production and transportation costs. Our findings also show an u-shaped relationship between land area and crop yield. Land size is negatively correlated with farm productivity indicators, whereas the impact of the square of land area is positively significant. This is consistent with the findings of Helfand and Levine (2007), Omotilewa et al. (2021), and Sheng et al. (2019). It is argued that small-scale farmers tend to use land more intensively, monitor their production activities more closely, and are more efficient in using their scarce resources (Ebers et al., 2017). However, if land area is large enough, farmers could adopt machinery and modern technologies in the production process, therefore fostering their productivity. With regard to village characteristics, the share of households with access to electricity is found to have a positive impact on agricultural productivity. An explanation is that electricity facilitates the adoption of machinery and accelerates agricultural mechanization processes. The impact is strongly significant in Cambodia and Laos, where only a limited share of the population has access to electricity. In addition, our results show that distance to markets is negatively associated with agricultural productivity in Vietnam. This could be explained by the fact that households living

in remote areas face several barriers in accessing information, credit, inputs, and modern technologies (Ebers et al., 2017).

From the estimation of the value of natural resource extraction, we find that increasing agricultural production could discourage households to extract natural resources. This result is in line with Illukpitiya and Yanagida (2010) who show that natural resource extraction is a decreasing function of agricultural efficiency. Increasing agricultural productivity makes farming activities more profitable, therefore, increasing the opportunity cost of extraction activities. In addition, raising agricultural productivity makes farmers wealthier, allowing them to substitute market goods for forest goods. Regarding the impact of shocks on natural resource extraction, our findings show that exploitation of natural resources plays an important role as a buffer to mitigate the impact of weather shocks and market shocks. This is reasonable as these shocks affect most households in a community. Consequently, safety-net mechanisms that depend on the community (e.g., borrowing money, receiving remittance) may become less viable because relatives, friends, and neighbors may also be negatively affected by the same shock. The impact of market shocks is strongly significant in Thailand. This is reasonable as the economy in Thailand is more developed, households get more involved in markets, and they are more likely affected by market shocks. This is consistent with our results in Figure 2, showing that Thai farmers are more likely to be affected by market shocks, and the damages due to market shocks are more severe than in the other surveyed countries. Our results also show that health shocks have negative impacts on natural resource extraction in all countries, but these are significant only in Laos and Thailand. It is argued that health shocks could have two-sided effects on natural resource extraction (Völker and Waibel, 2010). On the one hand, households are motivated to extract more natural resources to meet the increasing demand for health care treatment and compensate for income losses. On the other hand, reduced labor availability due to health shocks would lower the use of labor-intensive activities such as

extracting natural resources (Wunder et al., 2014). The significant impact in Laos could be because compared to other surveyed countries, the damage of health shocks is more severe (see Figure 2). This is in line with Wagstaff (2014) who shows that health shocks are more common and more costly than other types of shocks in Laos. The negative and significant impact of health shocks in Thailand is because this country is the most developed. Nearly all Thai households have access to the national health insurance scheme, and other coping strategies (such as borrowing, receiving remittances) could be more available, therefore they might rely less on natural resource extraction to satisfy the increasing demand for health care treatment.

For other control factors, households with older heads and more male members are found to extract more natural resources. This could be because natural resource extraction activities are time-consuming and highly labor-intensive; therefore, households with more labor force, particularly young labor force, can extract more natural resources. It is also argued that young households tend to rely more on natural resource extraction, as they have not yet accumulated sufficient assets, land, and other physical capital to serve as a buffer (Wunder et al., 2014). Better-off households (those with a higher value of total assets per capita) with higher education levels and owning more mobile phones appear to have a lower value of extraction output. This is because these households might have less access to remunerative response options; therefore, they rely more on natural resource-based coping strategies (Wunder et al., 2014). With regard to village characteristics, living in remote areas without access to electricity and far from markets is shown to motivate households to extract more natural resources. Angelsen et al. (2014) and Nguyen et al. (2020) also find that living in villages with lower degrees of market integration or far from markets would motivate households to extract more natural resources.

5. Conclusion

Natural resource extraction is among the most important livelihood strategies for rural households in many developing countries. However, in Southeast Asia and many other parts of the world, environmental resources are degrading at an alarming rate. Therefore, understanding the underlying factors of environmental resource dependence can help to reduce and prevent the degradation of environmental resources. Given an ambiguous interrelationship between shocks, agricultural productivity, and natural resource extraction, our study aimed to investigate these relationships by using a large dataset of 4,213 households collected in four Southeast Asian countries, namely Cambodia, Laos, Thailand, and Vietnam. Methodologically, we first applied OLS models to investigate the impact of shocks, including health shocks, weather shocks, and market shocks on agricultural productivity. Then, we applied the heteroscedasticity-based instrument approach to study the impact of agricultural productivity on natural resource extraction. Our study makes some important contributions to the literature and provides useful information for policymakers. First, we enriched our understanding regarding the impact of agricultural productivity on natural resource extraction, which received little attention in the previous literature with ambiguous findings. Second, we took into account the effect of shocks in examining the relationship between agricultural productivity and natural resource extraction, while previous studies tended to investigate the impact of shocks on agricultural productivity and natural resource extraction separately. Third, we dealt with endogeneity problems in estimating the impact of agricultural productivity on natural resource extraction, which had not been solved in previous studies. Fourth, previous studies on natural resource extraction were often site-specific, which made the generalization of the research findings difficult; our study was conducted in four different countries.

Our results provide several important policy implications. The first suggestion for all countries is that enhancing agricultural productivity should be prioritized as it discourages rural

households to extract natural resources. Second, the governments have to provide more assistance and support to farmers in mitigating the severe effects of weather shocks as these extreme events undermine not only agricultural productivity, but also push households into extraction activities. For Cambodia, supporting rural education, promoting local markets, facilitating rural households' access to electricity, and land defragmentation are recommended to enhance agricultural productivity and reduce households' reliance on extraction activities. For Laos, accelerating the development of the communication systems (use of mobile phones), facilitating rural households' access to electricity, and promoting education in rural areas should be given high priority. For rural Thailand, promoting education and providing more assistance and support to farmers in mitigating the severe effects of market shocks are highly recommended. For rural Vietnam, accelerating farm mechanization, land defragmentation, and supporting the development of communication systems and local markets, and promoting education should be encouraged.

Our study still had some limitations. First, our data are cross-sectional, therefore, we were not able to estimate the long-term impacts of shocks and agricultural productivity on natural resource extraction. Second, the extraction of natural resources might be embedded in the culture of some population groups in Southeast Asia but our data did not allow us to capture cultural factors. Third, also due to data limitations, we were not able to control for soil quality and altitude at household-level or parcel-level when estimating agricultural productivity. In addition, future studies should consider using measured weather data to validate the reported extreme weather events. Last, our study included only four countries. Extending the study to other countries would contribute to the generalization of the research findings for the Southeast Asian region.

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Appendices

A1. Name and definition of variables in regression models

Name	Unit	Definition
crop yield (ln)	PPP$ 2005	Value of all crops that households harvested in the last 12 months
weather shock	yes=1,no=0	Households suffer from at least one weather shock (flood, drought, storm, heavy rainfall, cold period) in the last 3 years
health shock	yes=1,no=0	Households suffer from at least one health shocks (death, illness) in the last 3 years
market shock	yes=1,no=0	Households suffer from at least one market shocks (changes of output and input price in the market) in the last 3 years
age head	years	Age of household head
share of literate members	proportion	Share of literate members per household
household size	members	Number of household members
male members	numbers	Number of household male members
total asset value per capita	2005 PPP$	Total value of assets that household owns
tractor value	2005 PPP$	Total value of tractors that household owns
mobile phones	numbers	Number of mobile phones households own
land area	hectare	Total land area
irrigated land area	hectare	Total irrigated land area
no of land plots	numbers	Number of land plots
share of rice-planted land	proportion	Share of crop land for planting rice
(village) electricity	proportion	Share of households in the village have access to electricity
(village) distance to market	kilometers	Distance from village center to the nearest market
(village) mountain	yes=1,no=0	Village is located in a mountain

A2. Collinearity test of estimations for crop yield

	Whole sample	**Laos**	**Cambodia**	**Thailand**	**Vietnam**
Variable	VIF	VIF	VIF	VIF	VIF
weather shock	1.10	1.07	1.07	1.15	1.07
health shock	1.08	1.04	1.03	1.06	1.06
market shock	1.04	1.03	1.13	1.06	1.03
age head	1.19	1.09	1.16	1.07	1.18
share of literate	1.56	1.5	1.46	1.07	1.25
household size	3.00	3.23	2.83	2.49	2.79
male members	2.60	2.9	2.53	2.16	2.41
total asset value per capita (ln)	1.92	3.02	1.88	1.48	1.66
tractor value (ln)	1.61	2.45	1.72	1.35	1.4
mobile phones	1.43	1.46	1.67	1.3	1.44
land area	4.36	8.35	6.58	4.39	9.34
land area squared	3.06	7.46	5.40	2.95	6.43
irrigated land area	1.27	1.07	1.13	1.07	1.91
no of land plots	1.56	1.41	1.48	1.69	1.34
share of rice-planted land	1.41	1.06	1.09	1.12	1.5
(village) distance to market	1.51	1.15	1.11	1.13	1.43
(village) electricity	2.88	1.39	1.30	1.14	1.11
(village) mountain	1.39	1.15	1.33	1.25	1.28
Stung Treng (Cambodia)	3.15				
Svannakhet (Laos)	4.22				
Buriram (Thailand)	2.69				
Ubon Ratchathani (Thailand)	2.80			1.55	
Nakkhon Phanom (Thailand)	1.79			1.63	
Ha Tinh (Vietnam)	2.07				1.93
Daklak (Vietnam)	2.20				2.08
Mean VIF	*2.12*	*2.32*	*1.99*	*1.61*	*2.18*

A3. Collinearity test of estimations for extraction output value

	Whole sample	**Laos**	**Cambodia**	**Thailand**	**Vietnam**
Variable	VIF	VIF	VIF	VIF	VIF
crop yield	1.54	1.20	1.19	1.13	1.31
weather shock	1.11	1.07	1.07	1.16	1.08
health shock	1.08	1.05	1.03	1.06	1.06
market shock	1.04	1.03	1.13	1.06	1.03
age head	1.19	1.11	1.17	1.07	1.18
share of literate	1.57	1.51	1.46	1.08	1.25
household size	3.00	3.23	2.83	2.49	2.79
male members	2.60	2.90	2.53	2.16	2.41
total asset value per capita (ln)	1.92	3.03	1.88	1.49	1.68
tractor value (ln)	1.62	2.53	1.73	1.36	1.41
mobile phones	1.43	1.46	1.67	1.30	1.44
land area	4.49	9.28	6.91	4.44	9.62
land area squared	3.09	7.89	5.49	2.96	6.48
irrigated land area	1.28	1.07	1.13	1.07	1.98
no of land plots	1.56	1.42	1.48	1.69	1.34
share of rice-planted land	1.44	1.06	1.09	1.17	1.58
(village) distance to market	1.51	1.15	1.11	1.13	1.44
(village) electricity	2.89	1.40	1.35	1.14	1.11
(village) mountain	1.40	1.15	1.34	1.26	1.29
Stung Treng (Cambodia)	3.31				
Svannakhet (Laos)	4.23				
Buriram (Thailand)	2.69				
Ubon Ratchathani (Thailand)	2.80		1.58		
Nakkhon Phanom (Thailand)	1.79		1.63		
Ha Tinh (Vietnam)	2.08				1.93
Daklak (Vietnam)	2.23				2.10
Mean VIF	*2.11*	*2.34*	*1.98*	*1.59*	*2.17*

A4. Impact of shocks on crop yield by countries

	OLS models			
	Cambodia	**Laos**	**Thailand**	**Vietnam**
weather shock	-0.149*	-0.059	-0.166***	-0.072*
	(0.088)	(0.070)	(0.038)	(0.041)
health shock	0.022	0.107	-0.025	-0.009
	(0.080)	(0.075)	(0.045)	(0.041)
market shock	0.218	0.071	-0.013	0.114
	(0.185)	(0.220)	(0.070)	(0.075)
age head	0.005*	0.006**	-0.002	0.002
	(0.003)	(0.003)	(0.002)	(0.002)
share of literate members	0.138	0.289**	0.281**	0.259**
	(0.159)	(0.131)	(0.117)	(0.107)
household size	0.010	-0.012	0.006	0.028
	(0.030)	(0.025)	(0.018)	(0.018)
male members	-0.028	-0.010	0.014	-0.037
	(0.038)	(0.038)	(0.024)	(0.028)
total asset value per capita (ln)	-0.009	-0.037	0.021	0.094***
	(0.029)	(0.046)	(0.016)	(0.022)
tractor value (ln)	0.019	0.062***	0.009	0.021**
	(0.014)	(0.021)	(0.006)	(0.009)
mobile phone	0.005	0.021	0.013	0.039**
	(0.044)	(0.036)	(0.014)	(0.015)
land area	-0.154***	-0.398***	-0.075***	-0.334***
	(0.038)	(0.058)	(0.018)	(0.055)
land area squared	0.004**	0.028***	0.002**	0.021***
	(0.002)	(0.006)	(0.001)	(0.005)
irrigated land area	0.015	-0.003	0.013	0.252***
	(0.050)	(0.045)	(0.021)	(0.040)
no of land plots	-0.005	0.112	0.028*	-0.018**
	(0.060)	(0.101)	(0.015)	(0.008)
share of rice-planted land	-0.134	-0.008	-0.481***	-0.545***
	(0.087)	(0.082)	(0.096)	(0.066)
(village) distance to market	-0.000	0.001	-0.001	-0.014**
	(0.002)	(0.002)	(0.002)	(0.006)
(village) electricity	0.530***	0.228**	0.160	0.088
	(0.155)	(0.098)	(0.201)	(0.153)
(village) mountain	0.156*	-0.149	-0.189***	-0.136***
	(0.093)	(0.174)	(0.061)	(0.046)
Constant	7.193***	6.394***	7.639***	7.438***
	(0.274)	(0.341)	(0.305)	(0.286)
province dummies	yes	yes		
No of observations	503	507	1578	1625
R^2	0.161	0.166	0.113	0.239
Adjusted R^2	0.130	0.135	0.102	0.229
P-value	0.000	0.000	0.000	0.000

Robust standard errors in parentheses; *** p<0.01, **p<0.05, * p<0.1

A5. Impact of shocks on crop income per ha by countries

	OLS models			
	Cambodia	**Laos**	**Thailand**	**Vietnam**
weather shock	-1013.991***	-113.881	-631.415***	-372.531*
	(328.189)	(107.430)	(200.875)	(218.288)
health shock	267.985	-40.951	-182.516	-191.524
	(329.819)	(166.958)	(185.599)	(228.183)
market shock	1118.417	170.295	-98.264	134.122
	(1374.893)	(438.462)	(297.768)	(469.259)
age head	21.847	8.671**	-5.836	-3.766
	(14.139)	(4.210)	(6.718)	(10.111)
share of literate members	224.385	445.854	768.625**	291.472
	(912.478)	(322.732)	(364.167)	(590.982)
household size	-40.663	-12.194	-8.281	-77.156
	(172.412)	(36.626)	(90.632)	(103.418)
male members	-101.010	42.235	34.823	182.846
	(102.227)	(58.301)	(102.094)	(127.585)
total asset value per capita (ln)	-29.508	-14.442	-105.141	356.840***
	(110.225)	(71.920)	(79.658)	(118.115)
tractor value (ln)	-4.915	-12.279	3.414	52.398
	(41.132)	(46.373)	(23.903)	(47.585)
mobile phone	91.565	134.504*	77.993	91.453
	(158.488)	(74.061)	(64.635)	(91.018)
land area	-280.360***	-511.087***	-275.798***	-1162.832***
	(91.555)	(145.279)	(85.181)	(221.753)
land area squared	6.947**	39.141***	5.838*	83.071***
	(3.256)	(13.636)	(3.004)	(22.468)
irrigated land area	182.514	-11.024	21.742	752.906***
	(232.649)	(96.674)	(71.028)	(145.317)
no of land plots	-643.676**	-184.773	-6.029	-147.544***
	(250.737)	(353.594)	(60.043)	(44.755)
share of rice-planted land	-1376.691***	-367.592*	-3057.478***	-3413.958***
	(336.379)	(211.437)	(634.995)	(459.364)
(village) distance to market	-2.721	-1.133	-3.098	-31.476*
	(5.557)	(2.273)	(12.450)	(18.624)
(village) electricity	1976.105***	-17.210	-32.002	517.968
	(684.363)	(146.669)	(683.918)	(648.239)
(village) mountain	551.236**	231.849	-651.603***	-235.287
	(230.569)	(340.356)	(213.254)	(272.894)
Constant	4279.595***	1667.794**	5604.879***	3973.426**
	(1406.202)	(835.999)	(1368.573)	(1603.260)
province dummies	-	-	yes	yes
No of observations	503	507	1578	1625
R^2	0.201	0.088	0.104	0.109
Adjusted R^2	0.171	0.055	0.093	0.098
P-value	0.000	0.000	0.000	0.000

Robust standard errors in parentheses; *** p<0.01, **p<0.05, * p<0.1

A6. Impact of crop yield on natural resource extraction by countries

	Heteroscedasticity-based Instrument models			
	Extraction output value (ln)			
	Cambodia	**Laos**	**Thailand**	**Vietnam**
crop yield (ln)	-0.34740**	-0.07444	-0.22996**	-0.10572
	(0.17619)	(0.18632)	(0.11720)	(0.11202)
weather shock	0.79583***	0.36835*	0.10855	0.38424***
	(0.28879)	(0.19940)	(0.12128)	(0.11288)
health shock	-0.17573	-0.45904**	-0.21421*	-0.09543
	(0.24274)	(0.19053)	(0.12321)	(0.11188)
market shock	0.11113	-0.48134	0.67574***	0.24537
	(0.43845)	(0.64059)	(0.19575)	(0.21721)
age head	0.00583	-0.02275***	-0.02453***	-0.01447***
	(0.00912)	(0.00702)	(0.00470)	(0.00442)
share of literate	-1.25385***	-0.89195**	0.23602	-0.87060***
	(0.44488)	(0.36324)	(0.30003)	(0.26788)
household size	0.12818	0.07107	0.01213	0.01997
	(0.10124)	(0.06833)	(0.05209)	(0.05153)
male members	-0.01118	0.10844	0.05536	0.12356*
	(0.13924)	(0.09888)	(0.07204)	(0.07305)
total asset value per capita (ln)	0.04710	-0.10064	-0.27416***	-0.29325***
	(0.09644)	(0.09771)	(0.04843)	(0.05832)
tractor value (ln)	0.07273	0.15083***	0.07222***	0.02832
	(0.04511)	(0.04755)	(0.01677)	(0.02325)
mobile phone	-0.14759	-0.20279**	0.01214	-0.08200*
	(0.14078)	(0.10104)	(0.04425)	(0.04506)
land area	-0.06961	0.00255	-0.06534	0.11270
	(0.10736)	(0.18414)	(0.04676)	(0.14684)
land area squared	-0.00225	-0.00053	0.00100	-0.00607
	(0.00380)	(0.01693)	(0.00124)	(0.02006)
irrigated land	0.30975***	-0.65762***	0.13885	-0.20216**
	(0.08136)	(0.19376)	(0.10259)	(0.09683)
no of land plots	0.18283	0.39632*	-0.03116	0.03254
	(0.16449)	(0.20501)	(0.04361)	(0.02706)
share of rice-planted land	-0.04224	-0.58367***	-0.10387	-0.27496
	(0.27153)	(0.21769)	(0.19440)	(0.17836)
(village) distance to market	0.00666*	0.00281	-0.00767	0.02403*
	(0.00388)	(0.00419)	(0.00700)	(0.01349)
(village) electricity	-0.88964**	-0.58427**	0.01052	0.40386
	(0.44165)	(0.25428)	(0.74306)	(0.49532)
(village) mountain	0.44689*	-0.09109	-0.21642	0.38064***
	(0.26832)	(0.29636)	(0.22411)	(0.12081)
constant	6.96641***	6.41024***	6.37226***	5.34599***
	(1.49980)	(1.39910)	(1.29293)	(1.08593)
province dummies	-	-	yes	yes
No of observations	503	507	1578	1625
R2	0.138	0.181	0.083	0.254
Adjusted R2	0.104	0.149	0.070	0.244
P-value	0.000	0.000	0.000	0.000
Underidentification	0.000	0.000	0.000	0.000
Overidentification	0.527	0.211	0.740	0.195
Weak identification	23.810	15.705	41.455	30.393

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors in parentheses; the underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis that all instruments are valid. For weak identification, Kleibergen-Paap rk Wald F statistics is reported.

A7. Impact of crop income on natural resource extraction by countries

	Heteroscedasticity-based Instrument models			
	Extraction output value (ln)			
	Cambodia	**Laos**	**Thailand**	**Vietnam**
crop income per ha	-0.00009***	-0.00015***	-0.00004**	-0.00003**
	(0.00003)	(0.00002)	(0.00002)	(0.00001)
weather shock	0.77334***	0.35476*	0.13614	0.38417***
	(0.28681)	(0.19685)	(0.11936)	(0.11187)
health shock	-0.11098	-0.44104**	-0.20602*	-0.08859
	(0.23884)	(0.19216)	(0.12258)	(0.11112)
market shock	0.12583	-0.69307	0.62870***	0.22213
	(0.41762)	(0.64585)	(0.19733)	(0.21755)
age head	0.00754	-0.02177***	-0.02427***	-0.01402***
	(0.00897)	(0.00700)	(0.00471)	(0.00440)
share of literate	-1.33326***	-0.98026***	0.18799	-0.92360***
	(0.44099)	(0.36323)	(0.29868)	(0.26598)
household size	0.13566	0.08968	0.01087	0.01352
	(0.09661)	(0.06659)	(0.05206)	(0.05144)
male members	-0.00406	0.08950	0.05127	0.15384**
	(0.13908)	(0.09617)	(0.07194)	(0.07419)
total asset value per capita (ln)	0.05099	-0.07874	-0.28399***	-0.30042***
	(0.09538)	(0.09815)	(0.04835)	(0.05704)
tractor value (ln)	0.06021	0.15565***	0.06691***	0.02770
	(0.04481)	(0.04591)	(0.01666)	(0.02297)
mobile phone	-0.10695	-0.13849	0.01067	-0.09112**
	(0.13929)	(0.10109)	(0.04393)	(0.04482)
land area	-0.11342	-0.10621	-0.03414	0.15811
	(0.10400)	(0.17221)	(0.04770)	(0.13432)
land area squared	0.00040	0.00302	0.00004	-0.01306
	(0.00389)	(0.01667)	(0.00133)	(0.01684)
irrigated land	0.32591***	-0.50548***	0.13400	-0.21052**
	(0.08229)	(0.18166)	(0.10190)	(0.09115)
no of land plots	0.17708	0.51803***	-0.04140	0.03045
	(0.16738)	(0.18542)	(0.04354)	(0.02700)
share of rice-planted land	-0.09135	-0.63173***	-0.03623	-0.25902
	(0.27603)	(0.21349)	(0.19159)	(0.17573)
(village) distance to market	0.00747**	0.00236	-0.00722	0.02421*
	(0.00372)	(0.00411)	(0.00704)	(0.01331)
(village) electricity	-0.83705*	-0.47839*	0.01879	0.45077
	(0.45917)	(0.25167)	(0.74136)	(0.50234)
(village) mountain	0.55765**	-0.14008	-0.17548	0.39668***
	(0.26395)	(0.29665)	(0.22373)	(0.12047)
constant	4.57514***	5.68500***	4.71159***	4.57742***
	(0.80027)	(0.68293)	(0.92896)	(0.74664)
province dummies	-	-	yes	yes
No of observations	503	507	1578	1625
R^2	0.147	0.184	0.087	0.254
Adjusted R^2	0.113	0.152	0.075	0.244
P-value	0.000	0.000	0.000	0.000
Underidentification	0.037	0.043	0.000	0.000
Overidentification	0.627	0.068	0.712	0.106
Weak identification	194.187	952.641	140.986	37.098

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors in parentheses; the underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis that all instruments are valid. For weak identification, Kleibergen-Paap rk Wald F statistics is reported.

A8. Impact of shocks on agricultural productivity (without village variables)

	OLS models	
	Crop yield (in ln)	**Crop income**
weather shock	-0.155***	-609.453***
	(0.026)	(110.930)
health shock	-0.026	-126.025
	(0.028)	(120.714)
market shock	0.073	166.107
	(0.051)	(262.576)
age head	0.005***	6.769
	(0.001)	(4.198)
share of literate members	0.530***	964.712***
	(0.061)	(266.436)
household size	-0.018	-81.456*
	(0.011)	(49.118)
male members	-0.023	51.578
	(0.017)	(58.805)
total asset value per capita (ln)	0.065***	89.613*
	(0.012)	(50.779)
tractor value (ln)	0.007	-20.544
	(0.004)	(17.594)
mobile phone	0.065***	160.243***
	(0.010)	(47.443)
land area	-0.210***	-505.859***
	(0.014)	(48.097)
land area squared	0.006***	15.741***
	(0.001)	(3.527)
irrigated land area	0.173***	353.699***
	(0.024)	(82.501)
no of land plots	0.053***	-17.054
	(0.007)	(27.797)
share of rice-planted land	-0.339***	-2204.989***
	(0.037)	(190.881)
Constant	6.915***	3182.752***
	(0.105)	(461.703)
No of observations	4213	4213
R^2	0.244	0.115
Adjusted R^2	0.241	0.112
P-value	0.000	0.000

Robust standard errors in parentheses; *** p<0.01, **p<0.05, * p<0.1

A9. Impact of shocks on agricultural productivity by countries (without village variables)

	OLS models			
Panel A: Impact of shocks on crop yield (ln)				
	Cambodia	**Laos**	**Thailand**	**Vietnam**
weather shock	-0.179**	-0.057	-0.194***	-0.060
	(0.089)	(0.069)	(0.038)	(0.041)
health shock	0.005	0.095	-0.026	-0.026
	(0.081)	(0.075)	(0.044)	(0.041)
market shock	0.268	0.077	-0.013	0.088
	(0.180)	(0.221)	(0.071)	(0.076)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
R^2	0.131	0.155	0.076	0.218
Adjusted R^2	0.104	0.129	0.067	0.211
P-value	0.000	0.000	0.000	0.000
Panel B: Impact of shocks on crop income per hectare				
	Cambodia	**Laos**	**Thailand**	**Vietnam**
weather shock	-1131.664***	-107.287	-636.016***	-445.777**
	(354.891)	(102.630)	(168.984)	(216.507)
health shock	199.318	-42.615	-140.335	-149.173
	(332.913)	(164.988)	(184.260)	(229.017)
market shock	1299.793	154.506	-85.345	206.198
	(1415.787)	(439.057)	(300.014)	(473.686)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
R^2	0.170	0.087	0.092	0.100
Adjusted R^2	0.145	0.059	0.083	0.091
P-value	0.000	0.000	0.000	0.000

Robust standard errors in parentheses; *** p<0.01, **p<0.05, * p<0.1

A10. Impact of agricultural productivity on natural resource extraction (without village variables)

	Heteroscedasticity-Based Instrument Models	
	Extraction output value (ln)	**Extraction output value (ln)**
crop yield (ln)	-0.666***	-
	(0.071)	-
crop income per hectare	-	-0.00006***
	-	(0.00001)
weather shock	0.369***	0.45711***
	(0.079)	(0.07793)
health shock	-0.108	-0.09476
	(0.080)	(0.07962)
market shock	0.187	0.12840
	(0.143)	(0.14288)
age head	-0.032***	-0.03573***
	(0.003)	(0.00283)
share of literate	-1.548***	-1.86989***
	(0.167)	(0.16293)
household size	0.078**	0.09508***
	(0.033)	(0.03292)
male members	0.176***	0.17626***
	(0.048)	(0.04771)
total asset value per capita (ln)	-0.230***	-0.26788***
	(0.034)	(0.03404)
tractor value (ln)	0.075***	0.06945***
	(0.013)	(0.01320)
mobile phone	-0.099***	-0.13025***
	(0.031)	(0.03082)
land area	0.139***	0.26040***
	(0.036)	(0.03419)
land area squared	-0.007***	-0.01208***
	(0.002)	(0.00191)
irrigated land	0.132**	0.01019
	(0.056)	(0.05320)
no of land plots	-0.147***	-0.18311***
	(0.020)	(0.01967)
share of rice-planted land	-0.953***	-0.82703***
	(0.100)	(0.09811)
constant	12.334***	7.90138***
	(0.569)	(0.28275)
No of observations	4213	4213
R^2	0.262	0.269
Adjusted R^2	0.259	0.266
P-value	0.000	0.000
Underidentification	0.000	0.000
Overidentification	0.009	0.000
Weak identification	142.834	129.855

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors in parentheses; the underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis of all instruments being valid. For weak identification, Kleibergen-Paap rk Wald F statistics is reported.

A11. Impact of agricultural productivity on natural resource extraction by countries (without village variables)

	Heteroscedasticity-Based Instrument Models			
	Extraction output value (ln)			
	Cambodia	**Laos**	**Thailand**	**Vietnam**
Panel A: The impact of crop yield				
crop yield (ln)	-0.412**	-0.175	-0.216*	-0.197
	(0.205)	(0.198)	(0.116)	(0.123)
weather shock	0.871***	0.361*	-0.094	0.377***
	(0.293)	(0.202)	(0.118)	(0.117)
health shock	-0.081	-0.434**	-0.357***	-0.166
	(0.247)	(0.192)	(0.123)	(0.118)
market shock	0.118	-0.387	0.607***	0.200
	(0.451)	(0.629)	(0.197)	(0.217)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
R^2	0.120	0.175	0.059	0.177
Adjusted R^2	0.091	0.148	0.050	0.169
P-value	0.000	0.000	0.000	0.000
Underidentification	0.000	0.000	0.000	0.000
Overidentification	0.577	0.342	0.750	0.272
Weak identification	27.102	18.181	60.048	38.257
Panel B: The impact of crop income				
	Cambodia	**Laos**	**Thailand**	**Vietnam**
crop income per hectare	-0.00011***	-0.00016***	-0.00004**	-0.00005***
	(0.00003)	(0.00002)	(0.00002)	(0.00001)
weather shock	0.85470***	0.35836*	-0.06182	0.38501***
	(0.29129)	(0.19930)	(0.11539)	(0.11551)
health shock	-0.05312	-0.47101**	-0.33934***	-0.16389
	(0.24245)	(0.19475)	(0.12189)	(0.11816)
market shock	0.17663	-0.66672	0.56618***	0.18224
	(0.41159)	(0.63343)	(0.19814)	(0.21623)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
R^2	0.132	0.176	0.063	0.180
Adjusted R^2	0.103	0.149	0.054	0.172
P-value	0.000	0.000	0.000	0.000
Underidentification	0.021	0.044	0.000	0.000
Overidentification	0.416	0.155	0.761	0.380
Weak identification	314.872	808.123	90.191	50.646

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors in parentheses; the underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis of all instruments being valid. For weak identification, Kleibergen-Paap rk Wald F statistics is reported.

A12. Impact of shocks on agricultural productivity

	Mixed-Effect Models (2 levels: household and village)	
	Crop yield (in ln)	**Crop income**
weather shock	-0.108***	-556.664***
	(0.025)	(127.128)
health shock	-0.006	-162.280
	(0.027)	(119.100)
market shock	0.066	70.204
	(0.047)	(256.848)
age head	0.001	1.672
	(0.001)	(4.419)
share of literate members	0.186***	612.688**
	(0.056)	(240.380)
household size	0.008	-31.555
	(0.010)	(47.205)
male members	-0.003	79.623
	(0.015)	(58.304)
total asset value per capita (ln)	0.047***	105.499*
	(0.012)	(55.791)
tractor value (ln)	0.016***	0.684
	(0.004)	(19.214)
having mobile phone	-0.004	-48.139
	(0.040)	(166.357)
land area	-0.127***	-412.145***
	(0.014)	(64.096)
land area squared	0.003***	11.805***
	(0.001)	(3.045)
irrigated land area	0.072***	264.176***
	(0.023)	(94.403)
share of rice-planted land	-0.312***	-2284.858***
	(0.047)	(277.793)
(village) distance to market	-0.002	-8.214
	(0.002)	(5.318)
(village) mountain	-0.191***	-382.211*
	(0.049)	(206.046)
Constant	7.688***	4064.384***
	(0.136)	(607.525)
province dummies	yes	yes
No of observations	4213	4213
Log pseudolikelihood	-4852.7026	-40540.236
P-value	0.000	0.000

Robust standard errors in parentheses; *** p<0.01, **p<0.05, * p<0.1

A13. Impact of shocks on agricultural productivity by countries

	Mixed-Effect Models (2 levels: household and village)			
Panel A: Impact of shocks on crop yield (ln, PPP per ha)				
	Cambodia	**Laos**	**Thailand**	**Vietnam**
weather shock	-0.174*	-0.056	-0.132***	-0.043
	(0.090)	(0.052)	(0.042)	(0.039)
health shock	0.023	0.116	-0.020	-0.021
	(0.064)	(0.074)	(0.046)	(0.043)
market shock	0.195	0.083	-0.001	0.120
	(0.167)	(0.151)	(0.068)	(0.077)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
Log pseudolikelihood	-612.73	-582.60	-1688.45	-1861.73
P-value	0.000	0.000	0.000	0.000
Panel B: Impact of shocks on crop income per hectare (PPP per ha)				
	Cambodia	**Laos**	**Thailand**	**Vietnam**
weather shock	-0.000***	-0.000***	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
health shock	0.719***	0.473***	0.129	0.345***
	(0.259)	(0.167)	(0.126)	(0.127)
market shock	-0.158	-0.428**	-0.188	-0.141
	(0.284)	(0.167)	(0.129)	(0.110)
control variables	-0.181	-0.365	0.636***	0.290
No of observations	(0.575)	(0.689)	(0.206)	(0.212)
Log pseudolikelihood	-4739.35	-4457.07	-15011.34	-15946.21
P-value	0.000	0.000	0.000	0.000

Robust standard errors in parentheses; *** p<0.01, **p<0.05, * p<0.1

A14. Impact of agricultural productivity on natural resource extraction

	Mixed-Effect Models (2 levels: household and village)	
	Extraction output value (ln)	**Extraction output value (ln)**
crop yield (ln)	-0.135***	-
	(0.048)	-
crop income per hectare	-	-0.000***
	-	(0.000)
weather shock	0.365***	0.363***
	(0.077)	(0.077)
health shock	-0.153**	-0.157**
	(0.076)	(0.076)
market shock	0.352**	0.345**
	(0.142)	(0.142)
age head	-0.017***	-0.017***
	(0.003)	(0.003)
share of literate	-0.562***	-0.569***
	(0.174)	(0.175)
household size	0.023	0.020
	(0.029)	(0.029)
male members	0.096**	0.100**
	(0.043)	(0.043)
total asset value per capita (ln)	-0.201***	-0.204***
	(0.035)	(0.035)
tractor value (ln)	0.064***	0.062***
	(0.013)	(0.013)
having mobile phone	0.025	0.024
	(0.108)	(0.109)
land area	-0.016	-0.012
	(0.034)	(0.033)
land area squared	-0.001	-0.002
	(0.001)	(0.001)
irrigated land	-0.028	-0.029
	(0.059)	(0.059)
share of rice-planted land	-0.254**	-0.285**
	(0.115)	(0.114)
(village) distance to market	0.009**	0.009**
	(0.004)	(0.004)
(village) mountain	0.418***	0.430***
	(0.123)	(0.124)
constant	5.405***	4.503***
	(0.497)	(0.357)
province dummies	yes	yes
No of observations	4213	4213
Log pseudolikelihood	-15011.34	-15946.21
P-value	0.000	0.000

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors in parentheses; the underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis of all instruments being valid. For weak identification, Kleibergen-Paap rk Wald F statistics is reported.

A15. Impact of agricultural productivity on natural resource extraction by countries

	Mixed-Effect Models (2 levels: household and village)			
	Extraction output value (ln)			
	Cambodia	**Laos**	**Thailand**	**Vietnam**
Panel A: The impact of crop yield				
crop yield (ln)	-0.211	-0.279**	-0.007	-0.072
	(0.145)	(0.139)	(0.072)	(0.073)
weather shock	0.811***	0.483***	0.137	0.346***
	(0.246)	(0.166)	(0.126)	(0.126)
health shock	-0.189	-0.392**	-0.185	-0.140
	(0.285)	(0.172)	(0.129)	(0.110)
market shock	-0.238	-0.365	0.638***	0.296
	(0.567)	(0.707)	(0.205)	(0.212)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
Log pseudolikelihood	-1195.89	-1117.94	-3482.78	-3542.90
P-value	0.000	0.000	0.000	0.000
Panel B: The impact of crop income				
	Cambodia	**Laos**	**Thailand**	**Vietnam**
crop income per hectare	-0.000***	-0.000***	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
weather shock	0.719***	0.473***	0.129	0.345***
	(0.259)	(0.167)	(0.126)	(0.127)
health shock	-0.158	-0.428**	-0.188	-0.141
	(0.284)	(0.167)	(0.129)	(0.110)
market shock	-0.181	-0.365	0.636***	0.290
	(0.575)	(0.689)	(0.206)	(0.212)
control variables	yes	yes	yes	yes
No of observations	503	507	1578	1625
Log pseudolikelihood	-1192.45	-1116.76	-3482.35	-3542.80
P-value	0.000	0.000	0.000	0.000

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors in parentheses; the underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis of all instruments being valid. For weak identification, Kleibergen-Paap rk Wald F statistics is reported.

Chapter 5. Remittances, Sanitation, and Child Malnutrition: Evidence from Rural Southeast Asia

Abstract

Understanding the linkages between remittances, sanitation, and child malnutrition is crucial for achieving the United Nations Sustainable Development Goal (SDGs) of access to clean water and sanitation for all. This study examines the impact of remittances on the propensity of having a flush toilet by rural households, and its impact on child malnutrition in rural Thailand and Vietnam. We use a four-wave panel dataset of rural households collected in 2007, 2010, 2013, and 2016 in six provinces in these two countries and employ an instrumental variable approach to address endogeneity concerns. Our results show that remittances facilitate the adoption of a flush toilet, and children from households without a flush toilet suffer more from wasting, underweight, and stunting. Furthermore, the impact of having a flush toilet on child health is heterogeneous across different child groups. Younger, female children and children from poor households benefit significantly more from having a flush toilet. Supporting rural households to have flush toilets is thus recommended. In addition, promoting rural education and public water systems could also significantly reduce child malnutrition among rural households.

Keywords: heteroscedasticity-based identification strategy; instrumental variable; emerging economies; Thailand; Vietnam

JEL Code: C14, F21; I12

1. Introduction

Health is the essential component of human well-being (Fedorov and Sahn, 2005; Deaton, 2007), and child health is a key indicator of economic development (Chen and Li, 2009). Growth failures experienced at a young age are associated with poor cognitive development and lower education attainments in the short run, and lower wage earnings, and higher risks of health impediments in the long run (Mani, 2014). Child health is one of the critical issues in the Sustainable Development Goals adopted by all United Nations (UN) member states in 2015. Even though much progress has been made in improving child health and reducing child mortality (Galiani et al., 2005; Terrelonge, 2014), ensuring good child health is still a challenge for the years to come. This challenge is especially relevant in low- and middle-income (LMI) countries (Cameron et al., 2019). According to the data from the UN Children Fund (UNICEF), while less than half of the world's children live in LMI countries, these countries host two in three of all stunted children and three in four of all wasted children (UNICEF, 2019). In these countries, children from rural households are more likely to suffer from health problems than those from urban centers, and this is the same for children from poor families (Venkataramani, 2011; Chen et al., 2017).

One of the major causes of child health problems in rural areas of LMI countries is the lack of or inadequate access to sanitation facilities. Among around 2.5 billion people (about one-third of the world population) who lack sanitation facilities, many are children in rural areas (UNICEF, 2018). Unsafe water, inadequate sanitation, and poor hygiene lead to the deaths of more than 1.5 million children every year, mostly among those under the age of five years (Usman et al., 2019). In addition, children from homes with safe water and improved sanitation have a higher probability of reserving health problems due to malnutrition than those coming from homes without either facility (Merchant et al., 2003). Inadequate sanitation cause diarrheal and other diseases which can be transmitted via the fecal-oral route. A flush toilet deserves a

very important role in preventing fecal pathogens from reaching the environment among many improved sanitation facilities. A private flush toilet at home is especially important for women and female children as it ensures their privacy and reduces the risk of sexual assault (Gonsalves et al., 2015; Jadhav et al., 2016). However, in rural areas of these countries, having a private flush toilet at home is still too far for many households. Limited budget has long been recognized as one of the major constraints for rural households to access improved sanitation facilities (WHO, 2008; Perard, 2018), including a flush toilet.

In this respect, remittances, typically referred to as the money and goods transferred to rural households by migrant workers working outside their origin communities, either in urban areas or abroad (Adams, 2011), are an income source that relaxes the budget constraint. In a number of emerging economies where high economic growth has created off-farm job opportunities in urban areas or industrial centers, remittances have increasingly become an important source of income for many rural households (Nguyen et al., 2019). Migrant members from rural households mainly live in urban areas and thus might understand more the health benefits of flush toilets. This might facilitate them to request their original households to purchase a flush toilet from the remittances that they send home.

In this paper, we document the impact of remittances on the propensity of rural households to have a flush toilet, and the impact of having a flush toilet on child malnutrition of rural households in two middle-income and emerging economies in Southeast Asia, Thailand and Vietnam. Our focus on these two countries lies in the fact that both countries have witnessed rapid economic growth during the last several decades. Thailand has made remarkable progress in economic development, moving from a low-income to an upper middle-income country over the last four decades. Vietnam also moved from one of the poorest countries in the world to a lower-middle income country over the same period (Huy and Nguyen, 2019). Due to rapid economic growth, the demand for labor in urban areas and industrial centers in both countries

has increased significantly. Consequently, the number of migrants from rural to urban areas has been on the rise, mainly to the Greater Bangkok metropolitan area in Thailand, and to Hanoi Capital, and Ho Chi Minh City in Vietnam (Amare and Hohfeld, 2016). Therefore, sending migrants to urban areas and industrial centers has become a livelihood strategy of rural households in Thailand and Vietnam. In addition, the two countries are among the top five recipients of international remittances in the East Asia and the Pacific region (WB, 2016).

Even though open defecation in Thailand and Vietnam is not popular as every household seems to have a private toilet, owning a flush toilet at home is still too expensive for most rural households (O'Donnell et al., 2009; Firestone et al., 2011). According to the WHO and UNICEF data, in 2015 only 23% of the rural population in Thailand owned a flush toilet[9]. A report from the WB Water and Sanitation Program estimates that in Vietnam, the costs of poor sanitation is more than US$ 287 million per annum and that poor sanitation accounts for nearly 7 million diarrhea cases, 2.4 million cases of scabies, helminths, hepatitis A and trachoma and 0.9 million malnutrition-related cases per annum and resulting into more than 9000 deaths per year in rural areas (WB, 2008). Coupled with the use of substandard latrines, more than 9.5 million people in rural Vietnam still release excreta into their surroundings (UNICEF, 2018).

In this context, examining how remittances impact child malnutrition through the ownership of a flush toilet provides valuable information for instrumenting sanitation and child health development programs in these two countries. In addition, as the health benefits of having a flush toilet might be different among different rural population clusters, it is also important to examine who benefits more. Thus, our research aims to address the following research questions: (i) to what extent remittances impact rural households to have a private flush toilet,

[9] See : https://washdata.org/data/downloads#THA for Thailand and https://washdata.org/data/downloads#VNM for Vietnam

(ii), how does a private flush toilet reduce child health problems, and (iii) how is the child health benefit of having a private flush toilet distributed with respect to age and gender of children, and welfare status of rural households. We used a dataset of rural households and villages collected in six provinces in 2007, 2010, 2013, and 2016 to answer these questions. We employed an estimation strategy that accounts for endogeneity concerns in our empirical analysis. Our results show that remittances facilitate rural households to have flush toilets. Children from households without a flush toilet suffer more from wasting, underweight, and stunting. Furthermore, female children, young children, and children from poor households benefit more from having a flush toilet. Our findings thus confirm remittances as a source to improve rural sanitation and the importance of improved sanitation to child health in middle-income countries.

The remaining of our paper is structured as follows. The following section (section 2) presents a literature review. Section 3 describes the data. Section 4 introduces a conceptual model on the linkages between remittances, sanitation, and child health, and describes our econometric specifications. Section 5 discusses the findings. Section 6 concludes.

2. Literature review

Given the increasing importance of remittances, numerous studies have investigated the impact of remittances on various aspects of rural life in many LMI countries, focusing on the original communities where migrants come from (Bell et al., 2015; Howard and Stanley, 2017). Most of these studies have found that remittances have a positive impact on poverty reduction (McKay and Deshingkar, 2014), on consumption (Zhu et al., 2014), on health improvement (Lu, 2013), on education (Binci and Giannelli, 2018; Askarov and Doucouliagos, 2020), and on investment (Jena, 2018). However, a few studies have found that remittances can negatively affect labour supply, education, and even economic growth (Adams, 2011).

Some studies have examined the impact of remittances on child health (Mosley and Chen, 2003; Antén, 2010; Kroeger and Anderson, 2014; Terrelonge, 2014). According to Howard and Stanley (2017), the possible mechanisms through which remittances can impact child health include an increase in household spending and a change toward more nutritional diets. Unfortunately, the evidence on the impact of remittances on child health is mainly through changes in food consumption. In this aspect, the impact is heterogeneous as well. For example, Chauvet et al. (2009) find that remittances significantly improve child health but are much more effective in improving health outcomes for children who belong to the richest households. This raises the question of whether it is possible to find a fairer channel through which children from poor households can also benefit as much as those from better-off households.

The impact of remittances on child health through improved sanitation has been paid much less attention (Checkley et al., 2004; Mara et al., 2010; Adida and Girod, 2011; Lim and Simmons, 2016; Pickering and Alzua, 2016; Szabo et al., 2018). Poor sanitation, for example the practice of open defecation, has been found to contribute increasingly to the probability of children being stunted and underweight (Rahman et al., 2020), and is one of the leading causes of infant mortality (Galiani et al., 2005b; Fink et al., 2011; Hathi et al., 2017). More specifically on toilet use, Hammer and Spears (2016) find that introducing toilets and promoting village sanitation in communities where open defecation is popular positively impacts children's height in their early years.

While these previous studies provide important insights, there are a number of issues that need further attention. First, previous studies have focused on the impact of remittances on more visible development and environmental challenges such as food and health care expenditure, poverty and inequality (Adams and Page, 2005), asset accumulation and investment (Adams, 1998; Chowdhury and Radicic, 2019), education (Terrelonge, 2014; Howard and Stanley, 2017), and natural resource management (Bierkamp et al., 2021). Much less attention has been

paid to the impact of remittances on facilitating rural households to have improved sanitation facilities, and no evidence on the impact of remittances on owning a flush toilet by rural households.

Second, while the theoretical relationship between improved sanitation and child health seems clear, empirical evidence is mixed. For example, Fink et al. (2011) find that access to improved sanitation is associated with lower mortality, a lower risk of childhood diarrhea, and a lower risk of stunting. However, Headey and Palloni (2019) report that improvements in sanitation predict significant reductions in diarrhea prevalence and child mortality but are not associated with changes in stunting or wasting. This is in line with Dangour et al. (2013) and Freeman et al. (2017), who find that the impacts of improved water, sanitation, and hygiene on child stunting and wasting are often statistically insignificant. In addition, the impact of having a specific improved sanitation facility, such as a private flush toilet, has also been largely ignored despite its important role in determining children's health of rural households.

Third, some previous studies used the incidence of some diseases to represent child health problems. For example, at the first sign, improved sanitation is directly related to diarrhea incidence, and thus this relationship can be easier to be observed (Pickering et al., 2015). But the diarrhea incidence has well-known flaws associated with seasonality, reporting bias, and other measurement errors (Headey and Palloni, 2019). In this respect, child anthropometric indicators are recommended (Thomas et al., 1990; Shrestha et al., 2020). However, some previous studies used only a single anthropometric indicator of child health (Haughton and Haughton, 1997; Gamper-Rabindran et al., 2010), either weight or height (enkataramani, 2011; Kee et al., 2017; Augsburg and Rodríguez-Lesmes, 2018). Such a single indicator approach is not able to provide a comprehensive assessment of child health status.

Four, the issue of sanitation has been focused more in South Asia, where open defecation has been more popular (Augsburg and Rodríguez-Lesmes, 2018; Spears, 2020), sub-Saharan Africa (Momberg et al., 2020; Tadadjeu et al., 2020), or Latin America (Gamper-Rabindran et al., 2010). The fact that a significant proportion of these studies are in low-income countries is understandable. However, that does not mean that we should ignore other regions and middle-income countries, where, to our understanding, have received much less attention, especially middle-income countries in Southeast Asia.

Last, methodologically, both remittances and having a flush toilet are likely to be endogenous. This includes reserve causality and omitted variable bias that need to be accounted (Bettin et al., 2012). For example, some previous studies used cross-sectional data (Skoufias, 1998; Antén, 2010; Usman et al., 2019) and employed an estimation strategy that do not allow controlling for these endogeneity concerns. This might provide biased estimates of the impact (Zhu et al., 2014).

We contribute to the current literature in several aspects. This is the first study that explicitly considers the linkages first between remittances received and a flush toilet owned by rural households, and then between having a flush toilet on malnutrition of children of these households. This allows us to document one of the most relevant channels through which remittances can impact children's health. Second, this study considers multiple anthropogenic child health problems, namely wasting, stunting, and underweight, which allows us to provide a more comprehensive assessment of the impact of having a flush toilet on child malnutrition. Third, we use a panel dataset and employ an instrumental variable (IV) approach to control the above described endogeneity concerns. Last, our study enriches the understanding of these issues in two middle-income countries, Thailand and Vietnam, in Southeast Asia, the region which has not been given sufficient attention in the sanitation literature.

3. Data and descriptive statistics

3.1 Data collection

We used the data from a longitudinal survey under the research project *"Poverty dynamics and sustainable development: A long-term panel project in Thailand and Vietnam"*[10]. The project aims to examine the economic dynamics of rural households in these two emerging economies (Klasen and Waibel, 2015). Three provinces in Thailand (Buri Ram, Nakhon Phanom, Ubon Ratchathani) and three provinces in Vietnam (Dak Lak, Ha Tinh, Thua Thien Hue) were selected as study sites (Figure 1) as these provinces are rural and agriculture is the primary livelihood of the population. The selected provinces in Thailand are in the Northern region, which accounts for a third of its population and a third of its area. However, they are resided by about 40% of Thailand's poor. The selected provinces in Vietnam are also commonly characterized by a high incidence of poverty and a high dependence on agriculture (Nguyen et al., 2020a). The sampling procedure includes three stages following the guidelines of the United Nations Department of Economics and Social Affairs (UN, 2005 and is described in Hardeweg et al. (2013) and Nguyen et al. (2017). At the first and second stages, sampled sub-districts/communes and then sampled villages were selected based on the size of the human population. At the third stage, ten households in each sampled village were randomly chosen with equal probability. The pre-determined sample had been identified as 2200 households in 220 villages from each country. The survey time is normally in May and June of the survey years, and data are collected for the previous 12 months, from May of the previous year to April of the survey year.

[10] For more information see https://www.tvsep.de/overview-tvsep.html, household and village questionnaires are available for free download from this page.

Figure 1: Study sites in Northeast Thailand and Central Vietnam

Two survey instruments were used for data collection, and both are structured questionnaires, one for households and answered by household heads and the other for villages and answered by village heads. The household questionnaire collects information for several socio-economic indicators such as individual household members (e.g., age, education, health, and employment status), livelihood strategies, and income generating activities (farm production including crop and livestock production, non-farm employment, and natural resource extraction), and migration of household members and remittances. The monetary data such as income (including remittances) and consumption are recorded in local currencies (Thai Baht and Vietnamese Dong) and then converted to international Purchasing Power Parity (PPP$) and adjusted to 2005 prices. Each interview took, on average, two hours and was conducted at households' homes. The village questionnaire captures important data of village's infrastructure and local characteristics such as access to the public water system (tap water), and distance from the

village to the provincial centre. Information needed for our study is recorded in specific subsections designated in the household questionnaire (e.g., for migration and remittances, toilet use, and child health of each household) and in the village questionnaire (access to public water system and distance to the provincial centre). The migration subsection records information on who has migrated, migration duration, destination location, the reasons for migration, and the remittances received by rural households. A migrant is defined as a household member who had migrated to other places for at least 180 days during the last 12 months. A similar definition has been used by Brauw and Harigaya (2007) and Brauw (2010) in their studies on the impacts of migration and remittances on rural household welfare. For toilet use, the household head was asked to choose one among the following options: private flush toilet (at home), shared flush toilet (in the village), private latrine (at home), shared latrine (in the village), and open defecation. A flush toilet is defined as a toilet that disposes of human waste by using water to flush it through a drainpipe to another location. According to WHO (2019), a flush toilet is an indicator of improved sanitation that ensures hygienic separation of human excreta from human contact. This question allows us to identify which household has a private flush toilet. Regarding child health, the data of each child were recorded in the section of household members where information on age (years of age for those older than five years old and months of age for those younger than five years old), education (school years), height (cm), weight (kg) and self-assessment of child health status was recorded.

3.2 Child health malnutrition indicators

We use anthropometric child health indicators, namely height, and weight together with age, to determine whether a child suffers from malnutrition, including stunting, wasting, and underweight. Stunting reflects the state that a child is too short for age and is caused by long-term poor nutrition or repeated infection resulting in poor nutrient absorption or utilization. It is considered an indication of long-term restriction of a child's growth potential. It is argued

that stunting is largely irreversible as recovering height is not as easy as regaining weight. Child wasting refers to a child who is too thin for his or her height. It often indicates recent and severe weight loss or the failure to gain weight due to disease or insufficiency of food intake. Child underweight refers to a child who is too thin compared to the average in his or her age. Underweight results from severe weight loss, disease, or insufficiency of food intake (WHO, 2021).

To determine whether a child suffers from stunting, wasting, or underweight, the standardized z-scores of height-for-age, weight-for-height, and weight-for-age are used. They are calculated as[11]:

$$Z_{iga} = \frac{x_{iga} - \mu_{ga}}{\sigma_{ga}} \quad (1)$$

where x is the ratio of height (cm) by age (year), or the ratio of weight (kg) by age (year) of child i with gender g and age a, respectively. μ_{ga} and σ_{ga} are the median and standard deviation of the reference group having the same gender g and age a. The median and standard deviation of the reference group is based on the WHO child growth standards[12]. A child is considered stunned, wasted or underweight if the respective z-score is lower than -2 (minus two). Since the reference data for stunting, wasting, and underweight are only available for children from zero to 15 years (age), 60 cm to 120 cm (height), and zero to 10 years (age), this paper examines these problems only for children under 15 years of age for stunting, 60 cm to 120 cm of height for wasting, and under 10 years of age for underweight in our sample.

[11] Z-scores is calculated by Stata command of Vidmar et al. (2013).
[12] See https://www.who.int/tools/child-growth-standards

3.3 Data description

Thus far, the TVSEP project has conducted seven survey waves in 2007, 2008, 2010, 2011, 2013, 2016, and 2017 in both Thailand and Vietnam. However, the pre-determined sample cannot be interviewed completely in 2008 and 2011. We, therefore, used only data from 2007, 2010, 2013, and 2016 for complete data and for the fact that these waves provide an equal time gap between the surveys (every three years). Our sample includes 16207 households with 4350 households in 2007, 4180 households in 2010, 3964 households in 2013, and 3713 households in 2016. Among these 16207 households, only 3505 households (22%) owned a flush toilet at the survey time.

Table 1 provides the descriptive statistics of some important variables regarding household and village characteristics of the sample and the household groups with and without flush toilets. On average, households with a flush toilet has a bigger household size and lower shares of children and labourers than those without a flush toilet. Households with a flush toilet come more from the majority ethnic group and are more male-headed. They also have higher educated heads and asset value per capita than the households without flush toilets. As anticipated, households with a flush toilet receive a higher amount of remittances. Regarding the village characteristics, it is surprising that households with a flush toilet live in the villages with less access to pipe water, even though the villages are closer to the provincial centre.

Table 1: Household and village characteristics for the whole sample and by having a flush toilet status

	Whole sample	Having a flush toilet	
	(n = 16207)	No (n = 12702)	Yes (n = 3505)
Household-level			
Household size (people)	5.46	5.40	5.68***, a
	(2.15)	(2.17)	(2.08)
Share of labourers (%)	63.84	64.17	62.64***, a
	(25.59)	(25.5)	(25.91)
Ethnic minority (%)	13.68	15.56	6.85***, b
	(34.36)	(36.25)	(25.26)
Male head (%)	76.2	74.96	80.68***, b
	(42.59)	(43.32)	(39.48)
Age of head (years)	54.83	54.79	54.99
	(13.67)	(13.91)	(12.74)
Schooling years of the head (years)	5.81	5.41	7.26***, a
	(3.61)	(3.35)	(4.14)
Asset value per capita (PPP$ 1000)	2.51	2.22	3.54***, a
	(5.8)	(4.75)	(8.49)
Remittance value per capita (PPP$ 1000)	0.11	0.11	0.13***, a
	(0.37)	(0.34)	(0.48)
Having migrant members (%)	59.99	58.42	65.68***, b
	(48.99)	(49.29)	(47.49)
Village level			
Access to public water (%)	58.41	60.86	49.5***, a
	(49.29)	(48.81)	(50)
Distance to provincial capital (km)	49.07	52.61	36.24***, a
	(34.67)	(34.93)	(30.47)

Standard deviation in parentheses; Statistic tests between household without and with flush toilet; [a]: Two-sample t-test; [b]: Non-parametric two-sample rank-sum test; *** p<0.01, ** p<0.05, * p<0.1.

Table 2 stacks the descriptive statistics of the sample by year and by remittance status. Overall, the share of households with a flush toilet increased significantly from about 10% in 2007 to more than 30% in 2016 in both groups of households without and with remittances. Households with remittances appear to have a larger household size, a higher share of labourers, and an older household head. Households without remittances belong to the ethnic majority more. They

also own more assets, and their heads have more years of schooling. Regarding the village characteristics, households with remittances live in villages with more access to public water but further away from the provincial centre.

Table 2: Household and village characteristics by year and remittance status

	2007 (n = 4350)		2010 (n = 4180)		2013 (n = 3964)		2016 (n = 3713)	
	Having remittances		Having remittances		Having remittances		Having remittances	
	No (n = 3336)	Yes (n = 1014)	No (n = 2919)	Yes (n = 1261)	No (n = 2568)	Yes (n = 1396)	No (n = 2428)	Yes (n = 1285)
Household level								
Having a flush toilet (%)	11.18	7.30$^{***, b}$	18.26	11.50$^{***, b}$	27.14	24.86^{b}	38.22	31.75$^{***, b}$
	(31.52)	(26.02)	(38.64)	(31.91)	(44.48)	(43.23)	(48.60)	(46.57)
Household size (people)	4.58	5.74$^{***, a}$	5.03	6.21$^{***, a}$	5.40	6.37$^{***, a}$	5.71	6.47$^{***, a}$
	(1.80)	(1.98)	(1.97)	(2.10)	(2.18)	(2.16)	(2.28)	(2.11)
Share of labourers (%)	63.08	76.58$^{***, a}$	66.18	76.60$^{***, a}$	61.39	65.57$^{***, a}$	51.34	64.57$^{***, a}$
	(25.19)	(18.82)	(25.50)	(18.13)	(26.13)	(23.90)	(27.56)	(22.46)
Ethnic minority (%)	16.10	6.11$^{***, b}$	16.31	6.58$^{***, b}$	17.80	7.38$^{***, b}$	16.47	7.70$^{***, b}$
	(36.76)	(23.97)	(36.95)	(24.81)	(38.26)	(26.15)	(37.10)	(26.68)
Male head (%)	79.98	75.54$^{***, b}$	78.69	74.94$^{***, b}$	76.25	73.64$^{*, b}$	72.86	71.52^{b}
	(40.02)	(43.00)	(40.96)	(43.35)	(42.57)	(44.07)	(44.48)	(45.15)
Age of head (years)	50.05	55.08$^{***, a}$	52.44	57.57$^{***, a}$	55.07	58.85$^{***, a}$	58.00	58.96$^{**, a}$
	(14.44)	(11.94)	(14.12)	(11.40)	(13.92)	(11.54)	(13.51)	(10.61)
Schooling years of head (years)	5.86	5.09$^{***, a}$	6.07	5.28$^{***, a}$	5.93	5.62$^{***, a}$	5.98	5.84^{a}
	(3.76)	(2.95)	(3.79)	(3.08)	(3.73)	(3.42)	(3.73)	(3.39)
Asset value per capita (PPP$ 1000)	2.03	1.91^{a}	2.24	1.95$^{**, a}$	2.74	2.33$^{*, a}$	3.60	3.03$^{**, a}$
	(3.70)	(3.01)	(4.77)	(3.26)	(7.72)	(5.45)	(8.28)	(5.82)
Village level								
Access to public water (%)	49.01	67.65$^{***, b}$	56.59	76.76$^{***, b}$	51.32	63.18$^{***, b}$	59.35	68.79$^{***, b}$
	(50.00)	(46.80)	(49.57)	(42.25)	(49.99)	(48.25)	(49.13)	(46.35)
Distance to provincial capital (km)	50.27	52.11^{a}	48.10	51.82$^{***, a}$	47.00	45.95^{a}	48.30	52.02$^{***, a}$
	(46.11)	(37.12)	(30.14)	(28.80)	(30.52)	(27.87)	(31.65)	(32.24)

Standard deviation in parentheses; Statistic tests between household without and with remittances; ^{a}: Two-sample t-test; ^{b}: Non-parametric two-sample rank-sum test; *** p<0.01, ** p<0.05, * p<0.1.

Table 3 presents some characteristics of children and their mothers. The total number of children (under 15 years) in the sample decreased from 3667 in 2007, to 2501 in 2010, to 1643 in 2013, and to 1253 in 2016. It appears that there is no significant difference in gender between children in households without and with a flush toilet. The difference in age of children from these two household groups was only significant in 2007. The data show that in households with a flush toilet, the mothers have higher years of schooling, but there are no significant differences in mother height and weight between these two household groups (with and without a flush toilet).

Table 3: Child and mother characteristics by year and by having a flush toilet status

	Whole sample (n = 9064)	2007 (n = 3667)		2010 (n = 2501)		2013 (n = 1643)		2016 (n = 1253)	
		Having flush toilet		Having flush toilet		Having flush toilet		Having flush toilet	
		No (n = 3174)	Yes (n = 493)	No (n = 1980)	Yes (n = 521)	No (n = 1136)	Yes (n = 507)	No (n = 714)	Yes (n = 539)
Age of child (years)	10.09	9.71	10.12$^{**, a}$	10.24	10.25 ^{a}	10.40	10.49 ^{a}	10.29	10.35 ^{a}
	(3.92)	(4.09)	(3.94)	(3.79)	(3.81)	(3.70)	(3.66)	(4.03)	(3.89)
Male child (%)	50.15	50.03	48.68 ^{b}	50.15	48.94 ^{b}	51.32	48.92 ^{b}	52.66	48.79 ^{b}
	(50.00)	(50.01)	(50.03)	(50.01)	(50.04)	(50.00)	(50.04)	(49.96)	(50.03)
Age of mother (years)	39.17	37.92	38.77$^{**, a}$	39.04	40.10$^{***, a}$	40.04	40.54 ^{a}	40.68	41.29 ^{a}
	(7.22)	(7.46)	(6.58)	(7.12)	(7.09)	(7.41)	(6.26)	(6.73)	(6.50)
Schooling years of mother (years)	5.93	5.66	6.60$^{***, a}$	5.67	6.78$^{***, a}$	5.68	6.80$^{***, a}$	5.78	7.04$^{***, a}$
	(3.62)	(3.43)	(4.06)	(3.42)	(3.95)	(3.50)	(3.93)	(3.73)	(4.01)
Height of mother (centimetres)	154.25	153.06	154.20$^{**, a}$	154.98	155.36 ^{a}	154.77	154.72 ^{a}	154.73	155.43$^{**, a}$
	(8.63)	(11.38)	(10.65)	(5.59)	(4.75)	(5.68)	(9.21)	(5.97)	(6.38)
Weight of mother (kilograms)	50.23	49.82	49.34 ^{a}	49.92	49.41 ^{a}	51.02	50.38 ^{a}	52.10	51.16$^{*, a}$
	(9.15)	(10.20)	(6.75)	(8.91)	(7.08)	(9.39)	(7.04)	(9.53)	(7.27)

Standard deviation in parentheses; Statistic tests between household without and with flush toilet; ^{a}: Two-sample t-test; ^{b}: Non-parametric two-sample rank-sum test; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Figure 2 presents the number of children suffering from stunting (from 0-15 years old), wasting (from 60-120 cm in height), and underweight (from 0-10 years old) and demonstrate several interesting issues. First, the number of children suffering from each of these health problems had reduced overtime during the 2007-2016 period. Second, in each year, female children seem

to be suffering less from stunting but more from wasting and underweight than male children (except 2017). Last, the differences in the numbers of affected between male and female children seem to be smaller over time. In 2007, nearly half of the total children suffered from stunting, which declined to around 33% in 2016. A decrease of 15% was observed in the share of underweight, which had plummeted from 32% in 2007 to 16% in 2016. By comparison, the share of children suffering from wasting reduced from 18% to 12% over this period.

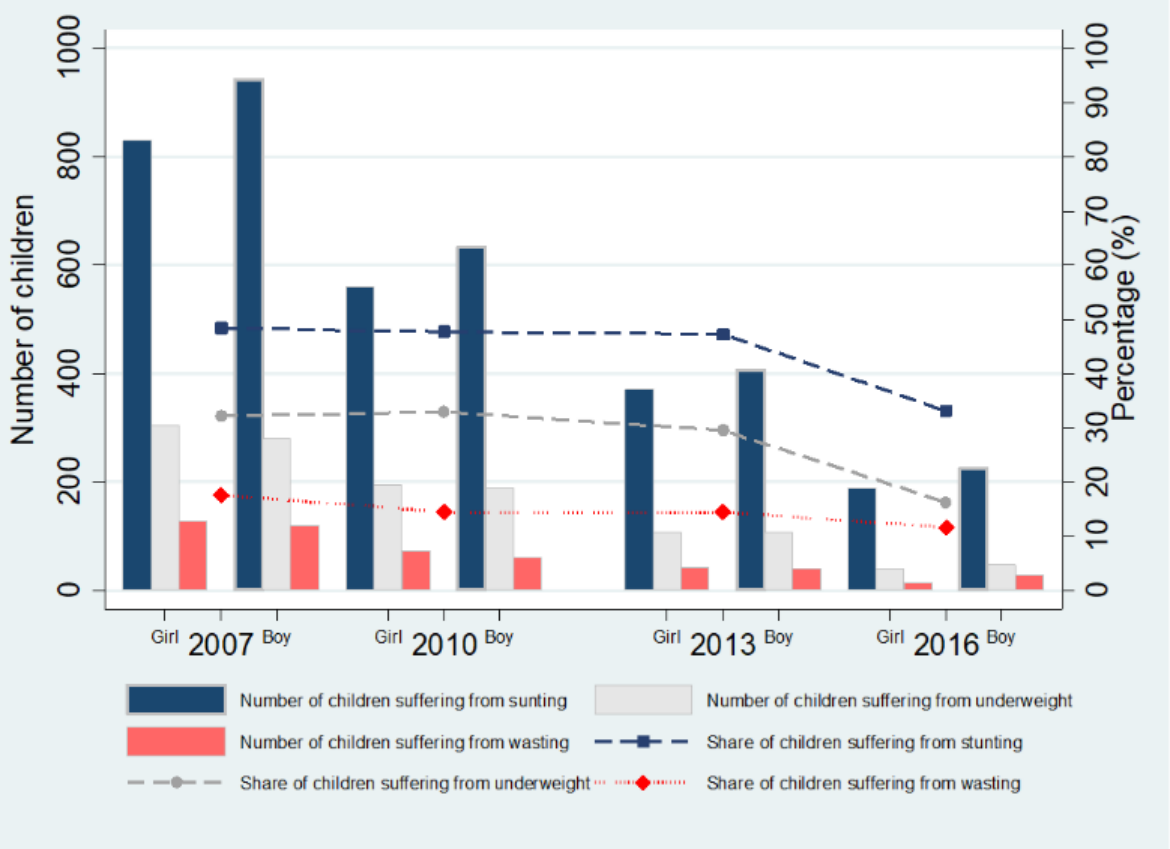

Figure 2: The numbers and shares of children suffering from stunting, wasting, and underweight by year

Figure 3 illustrates the share of households having flush toilets, the percentage of households having migrant members, and the average remittances per capita (in 2005 PPP US$) from 2007 to 2016. The changes in the share of households having a flush toilet, and those having migrant members are shown in the line chart. Meanwhile, the average value of remittances per capita is shown in the bar chart. In 2007, only 10% of households had a flush toilet, but this figure went

up to 36% in 2016. The share of households having migrants had increased from 40% to 67% over the period. The remittances per capita received was 90 PPP$ in 2007, and it increased to 130 PPP$ in 2016.

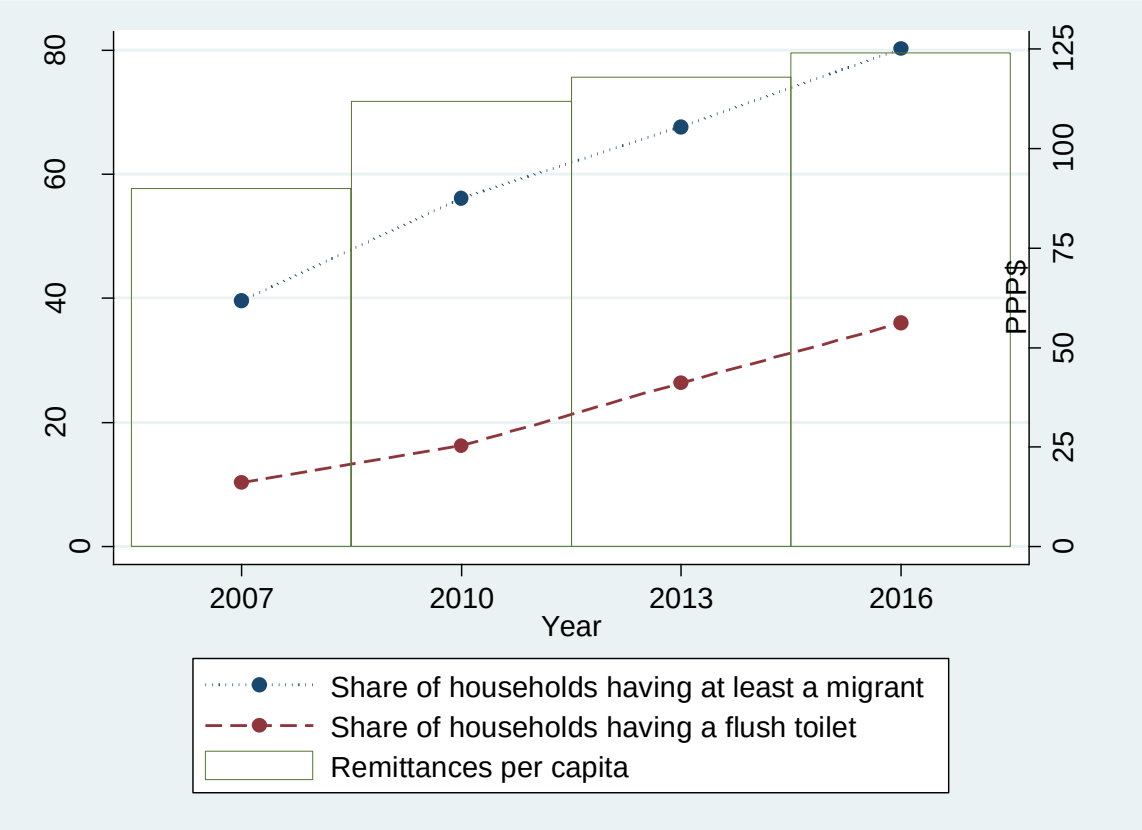

Figure 3: Shares of households with migrants and with flush toilets, and remittances per capita

4. Conceptual model and econometric estimation

4.1 Conceptual model

We extent the unitary household model with regards to the health condition of household members following Grossman (1972), Rosenzweig and Schultz (1983), Lee et al. (1997), and Currie (2000) to explore the relations between remittances, sanitation, and child health. Assuming a rural household in a developing country context where credit markets do not well function (Kassouf and Senauer, 1996), the household chooses child health (H), leisure (T^L), and consumption of goods and services (C), to maximize the household welfare function

$$\max U = u(C_t, T_t^L, H_t; \varphi_t) \quad (2)$$

where φ_t is the unobserved heterogeneity in tastes and preferences. Equation 2 is subject to the household budget constraint (equation 3) and time constraint (equation 4):

$$C_t + I_t = F_t + R_t \quad (3)$$

$$T_t = T_t^L + T_t^c + T_t^P \quad (4)$$

where I_t is the expense for health inputs, including a flush toilet, F_t is household labour income derived from household labor used for income generation T_t^P, R_t is household non-labour income including remittances, and T_t^c is time for child care.

The first-order conditions of the optimization exercise in equation 2 yield a conditional demand function for health input expenditure as

$$I_t = i(R_t, X_t, V_t) \quad (5)$$

where X_t is a vector of household characteristics and V_t a vector of location characteristics representing the environment where the household is living. Equation 5 indicates the theoretical relation between remittances and sanitation. Thus, the child health production function for child j of the household is derived as follows:

$$H_{tj} = h(I_t, M_t, T_t, D_{tj}, X_t, V_t) \quad (6)$$

where D_{tj} is a vector of the demographic characteristics of child j. M_t is a vector representing the characteristics of the mother. Other variables are defined as in equation 5. Equation 6 thus specifies the factors affecting child health status.

4.2 Identifying the impact of remittances on household's sanitation

The first step of our empirical analysis was to identify the impact of remittances on the ownership of a flush toilet by estimating the following model:

$$P_{ivt} = \alpha + \delta R_{ivt} + \gamma X_{ivt} + \beta V_{vt} + \varphi T_t + \eta N_n + \varepsilon_{ivt} \quad (7)$$

where P_{ivt} displays whether household i in village v at time t has a private flush toilet or not; R is the value of received remittances per capita; X is a vector of household characteristics; V is a vector of village characteristics; T is the year dummies; N is the provincial dummies; and ε_{ivt} is the error term. Regarding vector X, we included age (in years), education level (in years of schooling), gender (male or female), and ethnicity of the household head (ethnic majority or minorities). For vector V, we included whether the village has public water (pipe water) and the distance from the village to the provincial centre.

In estimating equation 7, there was a challenge that R_{ivt} is endogenous and the failure to capture unobservable household or village characteristics which affect both the ownership of a flush toilet and the value of received remittances would lead to invalid and biased estimates. We addressed this issue by employing the heteroscedastic-based instruments method proposed by (Lewbel, 2012). This method allows us to generate internal instrumental variables (IVs) to address this endogeneity concern. Assuming that remittances are determined as:

$$R_{ivt} = \gamma' + \delta P_{ivt} + \varphi' X_{ivt} + \xi_{ivt} \quad (8)$$

where X represents household and village variables. ξ is the residual.

In addition to the usual regression assumptions that the structural error terms in equations 7 and 8 are independent of each other and from X_{it}, the heteroscedasticity-based identification

strategy additionally assumes the existence of heteroscedasticity in ξ_{ivt}, and hence in R_{ivt}. Specifically, while the usual assumptions are

$$Cov(x'_{ivt}, \varepsilon_{ivt}) = Cov(x'_{ivt}, \xi_{ivt}) = Cov(x'_{ivt}, \varepsilon_{ivt}\xi_{ivt}) = 0 \quad (9)$$

it is now additionally assumed the heteroscedasticity in equation 8 that

$$Cov(x'_{ivt}, \xi^2_{ivt}) \neq 0 \quad (10)$$

Lewbel (2012) and Baum et al. (2013) suggest using $[x'_{ivt} - E(x'_{ivt})]\hat{\xi}_{ivt}$ as an internal instrumental variable (IV) in estimating equation 7, where $\hat{\xi}_{ivt}$ is the predicted residuals obtained by estimating equation 8 excluding P_{ivt} on the right-hand side. This is a promising instrument because $[X'_{ivt} - E(X'_{ivt})]\hat{\xi}_{ivt}$ is uncorrelated with ε_{ivt} as it is already assumed that $Cov(X'_{ivt}, \varepsilon_{ivt}\xi_{ivt}) = 0$ and it is correlated with R_{ivt} through ξ_{ivt} as in equation 8 (Lewbel, 2018).

We validated the IV by conducting several post-estimation tests. These tests include an underidentification test (a LM test based on Kleibergen and Paap (2006), a weak identification test using Cragg-Donald Wald F statistic statistics, and overidentification test based on the Hansen J statistic test. The results of these tests are reported in the lower section of Table 4. In addition, we also checked the Variance Inflation Factor (VIF) values for the potential perfect multicollinearity problem. The VIF values indicated no signal of this problem in estimating equation 7 (VIF results reported in appendix 1)

4.3 Examining the impact of improved sanitation on child health

The second step of our analysis was to examine the impact of having a flush toilet on child malnutrition. As having a flush toilet is endogenous, as shown in equation 7, we also employed the heteroscedasticity-based instrument approach described above to deal with the endogeneity

problem. The validity of our IVs was confirmed by the results of the post-estimation tests (LM test, Cragg-Donald Wald F test, and Hansen J test in table 5). The model is specified as follows:

$$U_{jivt} = \omega + \alpha P_{ivt} + \beta D_{jivt} + \gamma M_{jivt} + \delta X_{ivt} + \tau V_{vt} + \varphi T_t + \eta N_n + \xi_{jivt} \quad (11)$$

where U_{jivt} indicates whether child j from household i in village v at time t suffers from a malnutrition problem or not (stunting, wasting, or underweight); D is a vector of child characteristics (e.g., age, ethnicity, and gender); M is a vector of the characteristics of the mother (age, height, weight, education); other variables are defined in the previous equations; ξ_{jivt} is the error term.

As a robustness check for the impact of having a flush toilet, we also used the three-year lag of having a flush toilet (as the gap between surveyed waves is three years). The model is specified as:

$$U_{jivt} = \omega + \alpha P_{iv(t-3)} + \beta D_{jivt} + \gamma M_{jivt} + \delta X_{ivt} + \tau V_{vt} + \varphi T_t + \eta N_n + \xi_{jivt} \quad (12)$$

The value of α estimated from equation 12 can also indicate a long-term effect of having a toilet on child malnutrition.

Before estimating equations 11 and 12, the Variance Inflation Factor (VIF) values for the potential perfect multicollinearity problem were checked and indicate no signal of the perfect multicollinearity (VIF results reported in appendix 2).

4.4 Determining the heterogeneity of improved sanitation on child health

The health effects identified from equations 11 or 12 only provide a mean-based/homogenous estimation. Thus, in the last step of our empirical analysis, we further examined who benefit(s) more from having a private flush toilet. We focused on three child groups, namely, female

children (based on gender), young children (based on age), and children from poor households (based on asset value per capita). Thus, the original health child effect model specified in equation 11 was then modified by adding an interaction of having a flush toilet with the gender, with age of the child, and with the poverty status of the child's household. More specifically, the models are as follows:

$$U_{jivt} = \omega + \alpha P_{ivt} + \int_g P_{ivt} G_j + \beta D_{jivt} + \gamma M_{jivt} + \delta X_{ivt} + \tau V_{vt} + \varphi T_t + \eta N_n + \xi_{jivt} \quad (13)$$

where G_j is the dummy for the gender of child j,

$$U_{jivt} = \omega + \alpha P_{ivt} + \int_a P_{ivt} A_j + \beta D_{jivt} + \gamma M_{jivt} + \delta X_{ivt} + \tau V_{vt} + \varphi T_t + \eta N_n + \xi_{jivt} \quad (14)$$

where A_j is the age dummy for the gender of child j, and

$$U_{jivt} = \omega + \alpha P_{ivt} + \int_p P_{ivt} K_i + \beta D_{jivt} + \gamma M_{jivt} + \delta X_{ivt} + \tau V_{vt} + \varphi T_t + \eta N_n + \xi_{jivt} \quad (15)$$

where K_i is the dummy if the household of child j is asset poor.

Values of coefficients $\int$ from estimating equations 13, 14, and 15 indicate the heterogeneity in child health effects of having a flush toilet.

5. Results and discussion

5.1 Impact of remittances on having a private flush toilet

We run two models for the impact of remittances. In model 1, we used the value of remittances per capita as identified in equation 2. In model 2, we replaced the value of remittances per capita by a dummy variable if the household has a migrant member. Estimation results from these two models are reported in table 4. The models' summary statistics and diagnostics parameters, presented in the lower section of the table, show that all tests for overidentification,

underidentification, and weak instruments meet statistical requirements, confirming the validity and relevance of our models. In both models, year and provincial dummies are included.

Table 4: Impact of migration and remittances on the propensity of having a flush toilet

	Heteroskedasticity-based instruments	
	Model (1) with the value of remittances	Model (2) with dummy variable of migration
Remittances value per capita	0.057***	
	(0.013)	
Having migrant members		0.013
		(0.033)
Ethnic minority	-0.227***	-0.226***
	(0.020)	(0.020)
Household size	0.004**	0.003
	(0.002)	(0.003)
Share of labourers	0.000	0.000
	(0.000)	(0.000)
Male head	0.004	0.004
	(0.008)	(0.008)
Age of head	0.003***	0.002***
	(0.000)	(0.000)
Schooling years of head	0.018***	0.018***
	(0.001)	(0.001)
Asset poor	-0.108***	-0.112***
	(0.008)	(0.009)
Access to public water	0.047***	0.046***
	(0.013)	(0.013)
Distance to provincial capital	-0.001***	-0.001***
	(0.000)	(0.000)
constant	0.375***	0.376***
	(0.035)	(0.037)
Province and year dummies	yes	yes
No. of observations	16207	16207
R^2	0.309	0.307
Underidentification	0.000	0.000
Overidentification	0.182	0.301
Weak identification	2071.580	42.138
p-value	0.000	0.000

Robust standard errors clustered at the village level in parentheses; *** p<0.01, ** p<0.05, * p<0.1; The underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis being all instruments are valid. For weak identification, Cragg-Donald Wald F statistic is reported.

Our findings show that receiving more remittances significantly increases the likelihood that a rural household has a flush toilet, whereas the impact of migration is also positive but insignificant. This is reasonable as it is indicated in the literature that not all migrant members are able to send remittances home (Adams, 2011; Nguyen et al., 2019). Specifically, an increase in remittances per capita by 1000 $PPP would increase the probability of owning a flush toilet by 5%. It is explained that receiving remittances could relieve households from financial constraints and enable them to improve housing conditions. In addition, as migrant members are living in urban areas, they might understand more the benefits of a flush toilet, and thus they could transfer their awareness to their families (Lu, 2013). This finding indicates another important role of remittances in improving the sanitation facility of rural households who receive remittances.

For other control variables, ethnic minority households are less likely to own a flush toilet than ethnic majority households. It is reported that the uptake of improved sanitation facilities is lowest in the area with a high concentration of ethnic minorities (Rheinländer et al., 2010). This is reasonable as ethnic minority groups in Vietnam and Thailand generally have lower income and education levels than the ethnic majority (Nguyen et al., 2020b). Rheinländer et al. (2010) also report that ethnic minorities in Vietnam tend to defecate more in the open than the ethnic majority. Poor households with lower education levels are less likely to own a flush toilet, probably due to financial constraints. This finding is consistent with Minh et al. (2013), who find that non-poor households are more willing to pay for a flush toilet. Furthermore, households with an older household head and a larger household size are more likely to have a flush toilet. The distance from villages to provincial capital significantly and negatively affects the ownership of flush toilets. Our results also show that the availability of public water system in the village would facilitate rural households to have a flush toilet.

5.2 Impact of owning a private flush toilet on child malnutrition

Table 5 presents the estimation results for the impact of flush toilets on child health indicators, namely wasting, stunting, and underweight, as specified in equations 11 and 12. The models' summary statistics and diagnostics parameters, presented in the lower section of the table, show that all tests for overidentification, underidentification, and weak instruments meet statistical requirements, confirming the validity and relevance of our models. In all models, year and provincial dummies are included. The results from estimating equation 11 show that having a flush toilet is negatively and significantly associated with the likelihood of children suffering from wasting and underweight. The coefficients of this variable imply that having a flush toilet decreases the probability of wasting and underweight by 4.1% and 4.9%, respectively. It is reasonable as access to adequate sanitation could help prevent diseases like diarrhea, cholera, and parasitic diseases. As a result, this lowers the risk of child malnutrition and mortality (WHO, 2019a).

As a robustness check, the results from estimating equation 12 in which the three-year lag of having a flush toilet was used show that having a flush toilet is significant to reduce all wasting, stunting, and underweight, respectively. Having a flush toilet decreases the probability of wasting, stunting, and underweight by 7.7%, 7.5%, and, 10.4%, respectively. The significant impact of the three-year lag of flush toilets on stunting could be explained by the fact that stunting, based on height-for-age, is the result of long-term nutritional deprivation or chronic illnesses. In contrast to short-term indicators such as underweight (based on weight for age) which could respond rapidly to food intake, the state of stunting normally cannot improve over a short period of time (Fukuda-Parr and Orr, 2014). The negative and significant association between having a flush toilet and child malnutrition indicators confirms the importance of this sanitation facility in improving the health of children, even in middle-income countries.

Table 5: Impact of having a flush toilet on child health

	Heteroskedasticity-based instruments					
	Short-term impact of improved sanitation			Long-term effect of improved sanitation		
	Wasting	Stunting	Underweight	Wasting	Stunting	Underweight
Flush toilet (t)	-0.041*	-0.016	-0.049*			
	(0.022)	(0.022)	(0.027)			
Flush toilet (t-3)				-0.077***	-0.075***	-0.104***
				(0.028)	(0.027)	(0.034)
Household size	-0.003	0.012***	-0.006	-0.005	0.009*	-0.002
	(0.004)	(0.004)	(0.005)	(0.007)	(0.005)	(0.009)
Share of labourers	0.009	0.016	-0.000	0.012	0.046*	0.065*
	(0.022)	(0.019)	(0.024)	(0.035)	(0.025)	(0.037)
Male head	0.000	-0.001*	-0.001*	0.000	0.000	-0.001
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Ethnic minority	0.013	0.007	0.046*	-0.032	0.020	0.024
	(0.018)	(0.020)	(0.027)	(0.023)	(0.026)	(0.038)
Age of child	-0.004	0.035***	0.040***	0.089***	0.069***	0.039
	(0.011)	(0.006)	(0.010)	(0.031)	(0.016)	(0.032)
Age of child squared	-0.001	-0.002***	-0.002*	-0.008***	-0.004***	-0.002
	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.002)
Age of child cubed	-0.001	0.000	0.000	-0.001	0.000**	0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
Male child	0.013	0.046**	-0.021	-0.000	-0.014	-0.008
	(0.022)	(0.021)	(0.022)	(0.039)	(0.033)	(0.047)
Asset poor	0.037**	0.048***	0.055***	0.052**	0.073***	0.024
	(0.016)	(0.014)	(0.018)	(0.025)	(0.023)	(0.032)
Age of mother	0.001	-0.003***	-0.001	-0.000	-0.005***	-0.003
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
Schooling years of mother	-0.004*	-0.008***	-0.006***	-0.008***	-0.006**	-0.013***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
Height of mother	0.001	-0.006***	-0.002**	-0.000	-0.004**	-0.004*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Weight of mother	-0.003***	-0.004***	-0.007***	-0.003**	-0.005***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Distance to provincial capital	0.000	0.000	-0.000	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Access to public water	-0.029*	-0.036**	-0.059***	-0.009	-0.042*	-0.066**
	(0.016)	(0.017)	(0.021)	(0.022)	(0.022)	(0.031)
constant	0.253*	1.573***	0.958***	0.130	1.232***	1.289***
	(0.134)	(0.130)	(0.162)	(0.316)	(0.272)	(0.349)
Province and year dummies	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	3254	9064	4254	1231	4438	1712
R^2	0.040	0.102	0.105	0.044	0.094	0.092
Underidentification	0.000	0.000	0.000	0.000	0.000	0.000
Overidentification	0.839	0.965	0.971	0.128	0.834	0.126
Weak identification	162.605	295.762	159.859	94.610	270.628	132.761
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Robust standard errors clustered at the village level in parentheses; *** p<0.01, ** p<0.05, * p<0.1; The underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis being all instruments are valid. For weak identification, Cragg-Donald Wald F statistic is reported.

For other control variables, living in poor households with a larger household size and a male head would increase the probability of stunting. This could be because that households with a larger household size generally have lower income per capita and less available resources for child's health and education (Horton, 1986; Shehzad, 2006). This is in line with Augsburg and Rodríguez-Lesmes (2018), who show a negative association between height growth of children and household size. Our findings also show that ethnic minority children are more likely to suffer from underweight than children from the ethnic majority. WB (2009) also reports that although Vietnam has experienced impressive progress in reducing child undernutrition over the past two decades, undernutrition is still widespread among ethnic minority children, and the disparity between the ethnic majority and minorities is widening. In both Thailand and Vietnam, ethnic minority households generally have lower living standards and lower education levels than the ethnic majority.

Furthermore, early marriage and adolescent pregnancy are still common in ethnic minority groups. Age and education levels of the mother are negatively associated with the likelihood of stunting. This is reasonable as older mothers with higher education levels might have more experience and more knowledge on nutrition, healthcare; therefore, they are better at taking care of children (Chen and Li, 2009). Usman et al (2019) also show that children of younger mothers are more likely to suffer from illnesses. Mother height and weight are negatively associated with the likelihood of stunting, wasting, and underweight, which is consistent with Sujarwoto and Tampubolon (2013), who show that the health status of mothers significantly affects the health of their children. For village characteristics, the availability of public water system in the village is negatively correlated with the likelihood of stunting, wasting, and underweight. This is reasonable, as public water systems could improve the safety, quantity, and reliability of water supply. Unsafe water could pose children to severe illnesses such as diarrhea, cholera,

causing malnutrition or make it worse. It is argued that a malnourished children cannot get better without safe water, despite how much food they eat (UNICEF, 2021).

5.3 Heterogeneity in the child health impact of owning a private flush toilet

Table 6 summarizes the heterogeneous impact of owning a flush toilets on child health with respect to the gender and age of children and the poverty status of their households. Full regression results are reported in appendices 3, 4, and 5. With regard to age, the coefficient of the interaction between age and flush toilet is positive in the estimation for wasting, implying that younger children benefit more from the ownership of a flush toilet. This is reasonable as young children are more likely to be suffering from water and fecal-related diseases (Usman et al., 2019). Pickering et al. (2015) also show that having a toilet improves height and weight for younger children than older ones.

Table 6: Heterogeneity in health child impact of having a flush toilet

	Heteroskedasticity-based instruments		
	Wasting	Stunting	Underweight
Interaction between toilet and poverty			
Flush toilet($year_t$)*Asset poor	-0.075***	-0.070*	-0.021
	(0.028)	(0.040)	(0.040)
Flush toilet($year_{t-3}$)*Asset poor	-0.047	0.068	0.016
	(0.033)	(0.052)	(0.051)
Interaction between toilet and child gender			
Flush toilet($year_t$)*Male child	0.007	0.008	0.048
	(0.025)	(0.025)	(0.029)
Flush toilet($year_{t-3}$)*Male child	0.027	0.017	0.185***
	(0.030)	(0.034)	(0.049)
Interaction between toilet and child age			
Flush toilet($year_t$)*Age of child	0.008**	0.002	-0.000
	(0.004)	(0.003)	(0.005)
Flush toilet($year_{t-3}$)*Age of child	0.021***	0.002	0.001
	(0.007)	(0.006)	(0.010)

Robust standard errors clustered at the village level in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Full results in appendices 3-5

Regarding the gender of children, the coefficient of the interaction between males and owing a flush toilet (thrre-year lag) is positive in the estimation for underweight, signifying that girls benefit more from access to a flush toilet than boys do. This finding is in line with Augsburg and Rodríguez-Lesmes (2018), who report that girls significantly benefit more from the improvement of sanitation facilities, whereas the impacts on boys are not significant. UNICEF (2021) also argues that the lack of adequate sanitation impacts girls more severely than boys. Using shared sanitation facilities and open defecation could put girls at risk of sexual assault and prevent them from safely managing their monthly menstrual cycles. Due to privacy and safety issues, girls might refrain from urinating and defecating for many hours, consequently, causing severe illnesses such as urinary tract infections (Gonsalves et al., 2015; Jadhav et al., 2016).

The coefficient of the interaction between poverty status and having a flush toilet are positive in the estimation for wasting and stunting. This implies that children of poor households benefit more from having a flush toilet than those of non-poor households. This makes sense as poor children often face more disadvantages such as inadequate food, poor housing, limited access to health care, and living in substandard housing conditions. Therefore, they might have poorer health and are more vulnerable to illnesses. Our finding is in line with Pal (1999) who reports that female children and children from poor households in India benefit more from improved sanitation.

6. Conclusion

Examining the relationships between remittances and improved sanitation, and between improved sanitation and child malnutrition provides a crucial understanding for instrumenting sanitation and child health development programs in developing countries. Therefore, in this study, we investigated the impact of remittances on the propensity of having a private flush

toilet by rural households, its impact on child malnutrition, and the distributional aspect of the health impact. We used a dataset of more than 16000 rural households collected in four survey waves in two middle-income countries, Thailand and Vietnam, and employed the heteroscedasticity–based instrumental variable approach to address endogeneity concerns in impact assessments.

Our study finds that remittances enhance the adoption of a flush toilet, which in turn reduces the wasting, stunting, and underweight among children. Further, our study finds that younger children, female children, and children from poor households benefit significantly more from having a flush toilet. On the one hand, our findings document one of the channels through which remittances can contribute to the development of rural communities and confirm the importance of remittances in facilitating rural households to have one of the most important sanitation facilities, a flush toilet. On the other hand, it shows that having a flush toilet is more inclusive as it brings more benefits to more disadvantaged groups, female children, young children, and children from poor households. Supporting rural households to have flush toilets is thus recommended. In addition, promoting rural education and public water systems could also significantly benefit child health of rural households.

Even though our study provides valuable insights, it still has a number of limitations. First, our study considered only three malnutrition indicators, namely stunting, wasting, and underweight. Second, our data did not allow us to examine the impact of other sanitation facilities and also the impact of sanitation facility bundles. Third, our study covered only two emerging economies in Southeast Asia and only in a 10 year period (2007-2016). Considering the impact of various sanitation technologies and their bundles on more health child indicator in a more number of emerging economies in a longer period of time would allow us to generalize the impact of sanitation on child health more robustly. Future studies should address these limitations.

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Appendices

A1: Collinearity test (Impact of remittance and migration on owning a flush toilet)

Variables	VIF	VIF
Remittance value per capita	1.04	
Having a migrant member		1.43
Ethnic minority	1.4	1.41
Household size	1.08	1.26
Share of labourers	1.18	1.25
Male head	1.11	1.11
Age of head	1.35	1.39
Schooling years of head	1.33	1.33
Asset poor	1.13	1.13
Access to public water	2.08	2.04
Distance to provincial capital	1.13	1.13
2007	1.77	1.86
2010	1.68	1.72
2013	1.6	1.61
Buriam	2.7	2.65
Nakhon Phanom	2.94	2.91
Ubon Ratchathani	1.95	1.94
Ha Tinh	1.94	1.94
Thua Thien Hue	1.84	1.83
Mean	1.62	1.66

A2: Collinearity test (Impact of owning a flush toilet on child health malnutrition indicators)

Variables	VIF
Flush toilet	1.43
Household size	1.37
Male head	1.08
Share of labourers	1.52
Ethnic minority	1.69
Age of child	23.47
Age of child squared	24.68
Age of child cubed	4.62
Male child	3.68
Asset poor	1.20
Age of mother	1.79
Schooling years of mother	1.39
Height of mother	1.10
Weight of mother	1.45
Distance to provincial capital	1.11
Access to public water	2.00
2016	1.29
2013	1.25
2010	1.26
Buriam	2.03
Nakhon Phanom	2.16
Ubon Ratchathani	1.43
Ha Tinh	1.70
Thua Thien Hue	1.79
Mean	3.60

A3: Impact of owning a flush toilet on child health by poverty status

	Wasting	Stunting	Underweight	Wasting	Stunting	Underweight
Flush toilet (year$_t$)	-0.034*	-0.027	-0.058**			
	(0.019)	(0.020)	(0.025)			
Flush toilet*Asset poor	-0.075***	-0.070*	-0.021			
	(0.028)	(0.040)	(0.040)			
Flush toilet (t-3)				-0.074***	-0.073***	-0.102***
				(0.026)	(0.025)	(0.031)
Flush toilet (t-3)* Asset poor				-0.047	0.068	0.016
				(0.033)	(0.052)	(0.051)
Household size	-0.004	0.013***	-0.005	-0.008	0.010**	-0.004
	(0.004)	(0.004)	(0.005)	(0.006)	(0.005)	(0.008)
Share of labourers	0.013	0.022	-0.014	-0.011	0.057**	0.056
	(0.020)	(0.018)	(0.023)	(0.032)	(0.023)	(0.034)
Male head	0.000	-0.001***	-0.001	0.000	0.000	-0.001
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Ethnic minority	0.014	0.001	0.036	-0.017	0.023	0.053
	(0.016)	(0.019)	(0.025)	(0.020)	(0.025)	(0.036)
Age of child	0.006	0.034***	0.039***	0.071**	0.072***	0.041
	(0.010)	(0.006)	(0.010)	(0.028)	(0.015)	(0.031)
Age of child squared	-0.002**	-0.002***	-0.001*	-0.007***	-0.004***	-0.002
	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.002)
Age of child cubed	-0.000	-0.000	0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
Male child	0.013	0.058***	-0.019	-0.038	0.001	-0.021
	(0.022)	(0.020)	(0.021)	(0.035)	(0.031)	(0.045)
Asset poor	0.032**	0.045***	0.049***	0.022	0.068***	0.017
	(0.016)	(0.014)	(0.019)	(0.021)	(0.023)	(0.031)
Age of mother	0.001	-0.003***	-0.001	-0.001	-0.006***	-0.003
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
Schooling years of mother	-0.005**	-0.009***	-0.005**	-0.008***	-0.007***	-0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Height of mother	0.001	-0.006***	-0.002***	0.000	-0.005***	-0.005***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Weight of mother	-0.003***	-0.004***	-0.008***	-0.003**	-0.005***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Distance to provincial capital	0.000	0.000	-0.000	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Access to public water	-0.020	-0.033**	-0.055***	-0.013	-0.037*	-0.060**
	(0.014)	(0.016)	(0.019)	(0.018)	(0.021)	(0.028)
constant	0.191	1.635***	0.984***	0.208	1.348***	1.524***
	(0.124)	(0.124)	(0.157)	(0.278)	(0.252)	(0.324)
Province and year dummies	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	3254	9064	4254	1231	4438	1712
R^2	0.040	0.102	0.104	0.041	0.094	0.090
Underidentification	0.000	0.000	0.000	0.000	0.000	0.000
Overidentification	0.816	0.557	0.973	0.135	0.971	0.143
Weak identification	118.915	237.582	125.463	73.634	192.183	87.122
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Robust standard errors clustered at the village level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; The underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis being all instruments are valid. For weak identification, Cragg-Donald Wald F statistic is reported.

A4: Impact of owning a flush toilet on child health by child gender

	Wasting	Stunting	Underweight	Wasting	Stunting	Underweight
Flush toilet (year$_t$)	-0.030	-0.058***	-0.091***			
	(0.020)	(0.019)	(0.024)			
Flush toilet*Male child	0.007	0.008	0.048			
	(0.025)	(0.025)	(0.029)			
Flush toilet (t-3)				-0.076***	-0.096***	-0.201***
				(0.022)	(0.024)	(0.032)
Flush toilet (t-3)*Male child				0.027	0.017	0.185***
				(0.030)	(0.034)	(0.049)
Household size	-0.005	0.012***	-0.004	-0.004	0.009*	0.001
	(0.004)	(0.004)	(0.005)	(0.006)	(0.005)	(0.008)
Share of labourers	0.015	0.012	-0.004	0.015	0.046*	0.090***
	(0.021)	(0.018)	(0.022)	(0.031)	(0.025)	(0.035)
Male head	-0.000	-0.001*	-0.001	0.000	0.000	-0.001
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Ethnic minority	0.016	-0.011	0.049**	-0.029	0.008	-0.007
	(0.017)	(0.019)	(0.025)	(0.019)	(0.023)	(0.035)
Age of child	-0.005	0.033***	0.041***	0.091***	0.065***	0.044
	(0.011)	(0.006)	(0.009)	(0.027)	(0.015)	(0.031)
Age of child squared	-0.001	-0.002***	-0.002**	-0.008***	-0.004***	-0.002
	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.002)
Age of child cubed	-0.001*	0.000	0.000	-0.000	0.000**	-0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
Male child	0.013	0.042**	-0.023	-0.024	-0.015	-0.051
	(0.021)	(0.020)	(0.023)	(0.038)	(0.032)	(0.045)
Asset poor	0.044***	0.041***	0.057***	0.046**	0.065***	0.026
	(0.015)	(0.014)	(0.017)	(0.023)	(0.021)	(0.030)
Age of mother	0.002	-0.003***	-0.001	-0.001	-0.006***	-0.005**
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
Schooling years of mother	-0.004**	-0.008***	-0.006***	-0.007***	-0.005**	-0.014***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)
Height of mother	0.001	-0.006***	-0.002***	0.001	-0.006***	-0.005**
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Weight of mother	-0.002**	-0.004***	-0.007***	-0.004***	-0.005***	-0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Distance to provincial capital	-0.000	0.000*	-0.000	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Access to public water	-0.032**	-0.029*	-0.058***	-0.019	-0.045**	-0.035
	(0.015)	(0.016)	(0.020)	(0.020)	(0.022)	(0.030)
constant	0.144	1.577***	0.905***	0.066	1.462***	1.495***
	(0.123)	(0.123)	(0.147)	(0.283)	(0.248)	(0.321)
Province and year dummies	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	3254	9064	4254	1231	4438	1712
R^2	0.040	0.102	0.105	0.042	0.094	0.092
Underidentification	0.000	0.000	0.000	0.000	0.000	0.000
Overidentification	0.380	0.730	0.963	0.345	0.660	0.211
Weak identification	216.686	584.781	269.638	125.791	384.569	150.292
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Robust standard errors clustered at the village level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; The underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis being all instruments are valid. For weak identification, Cragg-Donald Wald F statistic is reported.

A5: Impact of owning a flush toilet on child health by child age

	Wasting	Stunting	Underweight	Wasting	Stunting	Underweight
Flush toilet (t)	-0.072**	-0.052	-0.063*			
	(0.032)	(0.041)	(0.036)			
Flush toilet*Age of child	0.008**	0.002	-0.000			
	(0.004)	(0.003)	(0.005)			
Flush toilet (t-3)				-0.222***	-0.110	-0.132*
				(0.058)	(0.071)	(0.080)
Flush toilet (t-3)*Age of child				0.021***	0.002	0.001
				(0.007)	(0.006)	(0.010)
Household size	-0.006	0.011***	-0.005	-0.006	0.009*	0.001
	(0.004)	(0.004)	(0.005)	(0.006)	(0.005)	(0.008)
Share of labourers	0.013	0.018	-0.005	0.033	0.052**	0.070**
	(0.021)	(0.018)	(0.022)	(0.032)	(0.025)	(0.035)
Male head	0.000	-0.001**	-0.001**	0.000	0.000	-0.001
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Ethnic minority	0.014	0.012	0.042*	-0.021	0.028	0.032
	(0.017)	(0.019)	(0.025)	(0.019)	(0.025)	(0.035)
Age of child	0.001	0.035***	0.043***	0.089***	0.072***	0.035
	(0.011)	(0.006)	(0.010)	(0.027)	(0.015)	(0.031)
Age of child squared	-0.002**	-0.002***	-0.002**	-0.008***	-0.004***	-0.001
	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.002)
Age of child cubed	-0.001*	0.000	0.000	-0.000	0.000**	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Male child	0.021	0.050**	-0.011	-0.016	-0.020	0.026
	(0.021)	(0.020)	(0.020)	(0.032)	(0.032)	(0.041)
Asset poor	0.034**	0.049***	0.051***	0.053**	0.069***	0.027
	(0.015)	(0.014)	(0.017)	(0.024)	(0.021)	(0.029)
Age of mother	0.001	-0.003***	-0.001	0.001	-0.005***	-0.005**
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
Schooling years of mother	-0.003*	-0.008***	-0.005**	-0.006**	-0.006**	-0.011***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Height of mother	0.000	-0.006***	-0.003***	0.001	-0.003**	-0.004*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Weight of mother	-0.002**	-0.004***	-0.007***	-0.004***	-0.006***	-0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Distance to provincial capital	0.000	0.000	0.000	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Access to public water	-0.028*	-0.034**	-0.051***	-0.038**	-0.048**	-0.067**
	(0.015)	(0.016)	(0.019)	(0.018)	(0.021)	(0.029)
constant	0.233*	1.621***	1.036***	-0.068	1.102***	1.244***
	(0.124)	(0.122)	(0.144)	(0.272)	(0.258)	(0.316)
Province and year dummies	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	3254	9064	4254	1231	4438	1712
R^2	0.040	0.102	0.104	0.045	0.094	0.090
Underidentification	0.000	0.000	0.000	0.000	0.000	0.000
Overidentification	0.831	0.083	0.460	0.250	0.573	0.319
Weak identification	224.572	491.150	243.320	145.432	341.321	150.215
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Robust standard errors clustered at the village level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; The underidentification test is an LM test based on Kleibergen and Paap (2006) rk LM statistics with the null hypothesis that the model is underidentified. The overidentification test is based on the Hansen J test with the null hypothesis being all instruments are valid. For weak identification, Cragg-Donald Wald F statistic is reported