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Crawford School Working Paper 1707 August/2017

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JEL Codes: Q18; Q15; Q24

Keywords: farmland preservation; general equilibrium; inequality; rice; Vietnam; welfare

Suggested Citation:

Chu, L., HTM. Nguyen, T. Kompas, K. Dang, and T. Bui, 2017, Optimal rice land protection in a command economy, Crawford School Working Paper 1707, August 2017. Crawford School of Public Policy, The Australian National University.

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Optimal rice land protection in a command economy

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Abstract

Agricultural land protection (ALP) is a standard policy response to growing food security concerns driven by urbanisation, population growth and uncertainty over climate change. However, if not supported by rigorous analysis, at least in terms of the correct scale of protection, ALP may result in a misallocation of resources, hampering economic efficiency and prosperity. Examining rice land policy in Vietnam, this paper aims to determine the optimal level of rice land protected against other crops and evaluates the impact of adopting the optimal policy. With a stochastic optimization model built on top of a computable general equilibrium framework and microsimulation techniques, applied to Vietnam's social accounting matrix and household survey data, we find that converting part of protected rice land into other crops enhances economic efficiency. While the efficiency gain could amount to billions of dollars, income inequality only improves slightly. Overall, the policy is relatively pro-rich, implying a trade-off between poverty reduction and economic efficiency for Vietnam, making some households in already poor areas worse off. Though calibrated to a specific case, our approach can be applied in land-use planning generally, highlighting the relevant tradeoffs and the search for needed optimal land-use policies.

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1. Introduction

Agricultural land protection (ALP) is applied in many countries in their transition to more modern and industrialised economies. Rapid urbanisation, being inevitable and often necessary for economic development, affects the supply of prime agricultural land (e.g. Firman, 2000; Ho and Lin, 2004; Deng et al., 2015). Furthermore, rapid population growth, slow improvements in agricultural productivity and reductions in land suitable for agricultural cultivation due to the effects of climate change, all lead to serious concerns over food security (Fazal, 2001; Montgomery et al., 2003; Schmidhuber and Tubiello, 2007; Godfray et al., 2010). In this context, interventions by governments to protect agricultural land are often recommended to cope with the decrease in farmland and to guard against uncertainties in food supply (Azadi et al., 2011). They are typically justified in mitigating the socio-economic impacts of farmland losses, affecting rural households in particular, and in addressing multiple land market imperfections that prevent the efficient consolidation of farmland in the first place, especially in transitional economies (Nelson, 1990; Deininger et al., 2003).

ALP is inherently contextual and highly complex (Deininger et al., 2003). These characteristics are due to the significant variation in the level of development, along with differences in political systems, institutions, history and the extent of agricultural land scarcity in each country (Alterman, 1997; Ding, 2003; Bengston et al., 2004; Tan et al., 2009; Lichtenberg and Ding, 2008). In spite of this diversity, ALP policies to date tend to share a common attribute, namely the lack of hard evidence to help designate the optimal amount of farmland to be protected.

We focus on a special case of farmland protected for a particular crop against all other crops. This policy is not uncommon in many developing countries where a crop is of high economic and political significance, so that protecting its land-use is a familiar option for policy-makers. Examples are the protection of rice land in Asian countries (e.g. Markussen et al., 2011; Fujita et al., 2009) or cotton land in Central Asia (Halimova, 2007). Research on this policy has been mostly restricted to its impact on welfare or efficiency (e.g. Kutzman, 2016; Giesecke et al., 2013; Markussen et al., 2011; Martini and Kimura, 2009; Fujita

et al., 2009; Kurosaki, 2008; Halimova, 2007; Nielsen, 2003; Brandt et al., 2002). Meanwhile, increasingly more studies measure how much farmland has been lost (e.g. Pandey and Seto, 2015; Gibson et al., 2015). However, few studies provide guidance on how much land should be protected to aid the decision-making process, not only in this special case, but also in general.

Nevertheless, the challenges to answering the question of “how much?” farmland should be protected are worth noting. First, farmland protection often has multiple goals from a policy making perspective, thus complicating an optimization exercise. Second, land allocation has an economy-wide impact, and therefore, should be analyzed using a general equilibrium framework nested within an optimization model. As a result, the computational exercise is demanding. Finally, it is also an exercise that demands a good deal of data, since, at the least, it requires information on returns to alternative land uses which is generally not available.

In this study, we attempt to determine how much farmland for a particular crop should be protected and thus not used for other crops. To do so, we use a stochastic optimization model built on top of a general equilibrium (GE) framework. While our model is applied to this special case, it can be utilized in a broader context where farmland is protected from all other purposes including non-agricultural ones. Regarding policy objectives, we consider economic efficiency, measured by changes in Gross Domestic Product (GDP). Due to practical constraints in data and computational capacity, our GE framework is basic. We complement our aggregate analysis using a micro-simulation on household data to measure equality using the Gini index, and provide insights on distributional impacts of the best policy option on households in various regions and of different wealth classes.

We choose Vietnam as a case study for a few reasons. First, Vietnam is a key rice exporter in the world rice market, which itself is thin and vulnerable to production shocks by key players (Timmer, 2010; Slayton, 2009; David and Huang, 1996). As a result, a stable and predictable rice land policy in Vietnam, supported by careful analysis, could reduce uncertainty over the rice supplies; while an arbitrarily set scale of rice land protection and

frequent adjustments in the policy, together with a politically-driven industrial structure here (Fulton and Reynolds, 2015; Markussen and Tarp, 2014), will likely add to volatility in world rice prices and supplies. Second, for Vietnam itself, rice-related policies have widespread impacts on household living standards, given that rice remains the main staple, especially for the poor, and that rice production involves roughly two-thirds of rural households (Vu, 2008). Finally, like many developing countries, Vietnam is currently under enormous pressure to use land more efficiently to enhance economic growth, while feeding its population, whose diet is shifting towards meat as their income increases (Kompas et al., 2015). Under these circumstances, a recent government decision to protect 7.0 million hectares of planted rice land, raises concerns over the arbitrary nature of this decision and what it is achieving.

Our results are generated using Vietnam’s social accounting matrix table (SAM) for 2011 and the Vietnam household living standard survey (VHLSS) data for 2010. We find that converting some protected rice land into other crops enhances both economic efficiency and overall income-based equality. However, detailed distributional impacts of the policy on both household income and consumption indicate that it is actually pro-rich, thus implying a trade-off between poverty reduction and economic growth for Vietnam; a country on course for transforming and modernising its rural economy to increase rural incomes and enhance economic development.

2. Background

In this section, we provide some background on the rice land protection in the world which is followed by a description of the situation and policy context in Vietnam.

2.1. Rice land protection in the world

Protection of rice land is important for world food security. Rice is the most important staple for poor people in the world and it is grown where most of them live, and thus an integral part of any measures to address world hunger and poverty (GRiSP, 2013). Being primarily produced and consumed in Asia, rice is of vital political and socio-economic importance in this region (GRiSP, 2013). For this reason, it is not uncommon to observe

government intervening in rice markets and distorting rice production, marketing and exports, making the world rice market and its relative control by a handful of countries in this part of the world more vulnerable to shocks (Timmer, 2010; David and Huang, 1996).

While Asian countries share the same desire to protect rice land, they apply different protection measures and achieve or bear varying levels of success or cost. For example, Japan is highly successful in maintaining rice land by providing substantial subsidies to farmers, but at the expense of competitiveness in the rice sector, and thus has to shoulder a high fiscal burden (Martini and Kimura, 2009). Indonesia, on the other hand, struggles to control land conversion due to rapid urbanization and the lack of effective counter-measures (Firman, 2000). Meanwhile, China succeeds in protecting agricultural land in quantity but fails in quality (Mao et al., 2012; Kong, 2014). At the end of the spectrum of strict rice land protection, Vietnam and Myanmar both have land designated for rice where farmers have no choice but to plant rice (Fujita et al., 2009; Markussen et al., 2011). Existing studies suggest that this policy results in inefficiency and hinders the poverty reduction process, especially in Vietnam (Markussen et al., 2011; Giesecke et al., 2013).

2.2. Rice and rice land protection in Vietnam

Rice is an integral part of Vietnamese culture and history, often referred to as a ‘rice civilization’ in the past. It was used by the current ruling Communist Party to gain broad-based support against the French colonists in a war that led to the independence of Vietnam in 1945 (Kerkvliet, 1997). For its role in the culture and history of Vietnam, golden rice paddy panicles are part of Vietnam’s national coat of arms, and in the symbols of all legislative, executive and judicial organizations.

The importance of rice in Vietnam is also driven by its role in economic development. At the household level, rice represents 60% and 25% of household calorie consumption and food expenditure of an average household, and 70% and 40% of poor households, respectively (Vu, 2008). Meanwhile, rice production involves about 66% of rural households and 77% of poor households (Ha et al., 2015). At the country level, rice export revenues contribute about 3% of total GDP (General Statistic Office, 2011), and used to be one of the most significant

contributors to Vietnam’s foreign reserves, when the country shifted, with agricultural and market reforms, from being a net food importer to now a key rice exporter in the world. This shift is often regarded as a remarkably successful transition story, lifting many Vietnamese people out of poverty, and certainly so compared to the prior period of agricultural collectivisation applied for more than three decades in the North and ten years in the South (Kompas et al., 2012).

Collectivised agriculture put Vietnam in an economic crisis (Pingali and Xuan, 1992; Che et al., 2001; Ravallion and Van de Walle, 2008; Kompas et al., 2012). Part of the reform process and the transition to a market economy was the promulgation of 1988, 1993 and 2003 land laws and their subsequent revisions in 1998 and 2001, and the most recent land law in 2013. Land users are always required to use land as per its ‘use purpose’, and the state reserves the right to monitor, change or grant permission to any changes to land use. However, not until the 2001 revision (Article 1, point #8) had rice land been explicitly specified in a land law. Before that, it was lumped together under agricultural land or annual crop agricultural land designations.

Quantitative indicators of rice land protection are articulated in Decree No. 63/NQ-CP, issued in 2009. In particular, 3.8 million hectares of rice land requires protection to yield an output of 41-43 million paddy rice/year so that food security in Vietnam is ensured by 2030. Furthermore, Resolution 17/2011/QH13 issued in 2011 details that 3.2 out of 3.8 million hectares of protected rice land must be land where (at least) two crops of rice are planted annually, implying a total of 7 million hectares of planted rice land. This ALP-by-zoning measure is undertaken on the grounds that the government, the sole land owner in Vietnam by Constitution, has the ultimate power on land use which it classifies as of ‘national importance’ (article 54, Vietnam’s Constitution). To facilitate this rice land protection, Decree 35/2015/ND-CP issued in 2015 provides measures to support (or not) rice farmers and procedures for conversion of rice land into other agricultural crops or production activities. In particular, rice land can be converted in a way that does not substantially change the heavily funded irrigation system, and rice can be planted again easily on the converted

land (Article 4, Decree 35/2015/ND-CP). In addition, the government has been explicitly encouraging expansion of cultivated land for maize to reduce imports of livestock feed which Vietnam increasingly needs (Decision 899/QD-TTg promulgated in 2013 on restructuring Vietnam’s agriculture). While using rice land for aquaculture is another option approved by the government, this kind of conversion is limited to delta regions, notably the Mekong, and would involve a substantial cost. Any other use of rice land for non-agricultural purposes is not allowed by the government given its concerns over food security.

Thus far Vietnam’s administrative measures have been largely successful in land rice protection. Planted rice land in Vietnam has remained stable at roughly 7.5 million hectares since 2001 (General Statistic Office, 2016b, 2011). However, this rice land protection policy, together with various kinds of support and subsidies provided to rice farmers, results in an apparent inefficiency; notably, some rice land being left idle due to low incomes from rice production, coupled with a lack of crop choice, compared to higher returns and land shortages for other crops (VOV, 2013; Markussen et al., 2011; Tien et al., 2006). Consequently, rice farmers cannot maximize their profits due to the lack of freedom in crop choice, the rice sector is not very responsive to market signals and consumers are made worse off (Markussen et al., 2011; Giesecke et al., 2013). Thus, an adjustment towards more efficient land use can potentially improve Vietnam’s prosperity, especially for rural households who account for two-thirds of Vietnam’s population.

3. Methodology

We overlay a stochastic dynamic optimization model on top of a GE framework to answer the question how much rice land should be protected in Vietnam. A GE framework is needed to evaluate the economy-wide impact of land allocation while a dynamic optimization routine is required to investigate how much rice land would generate the highest real GDP in the medium-term. To mimic the situation where Vietnam is an open economy, thus being exposed to exogenous shocks in the world market, we propose a stochastic optimization

dynamic problem in the form

$$\max_{0 \leq r \leq 1} \sum_{t=1}^T \left\{ \left(\frac{1}{1+\rho} \right)^{t-1} \mathbb{E}_u \{ [\text{GDP}_t(r) - \text{GDP}_t(0)] | u \} \right\} \quad (1)$$

where ρ is a discount rate; $\mathbb{E}$ is an expectation operator, u are random noises caused by exogenous factors; $T = 10$ is the actual planning horizon in Vietnam; given the realisation of u , $\text{GDP}_t(r)$ is the real GDP at year t associated with a proportion r of rice land converted into land for other crops while $\text{GDP}_t(0)$ is the real GDP at year t when no rice land is converted at all. Throughout the planning horizon, the conversion ratio remains constant to be consistent with the policy-making practice in Vietnam. Our objective is to find the value for the conversion ratio r that maximizes the total real GDP over the planning horizon. Technically, r can be negative in our model, that is, more rice land needs to be protected than currently. However, intuitively, rice area is apparently over-protected in Vietnam as discussed in Section 2. Under this circumstance, our discussion is limited to the cases of non-negative r (while results for the cases of negative r are available upon request).

With a GE framework nested inside, our stochastic dynamic optimization problem is computationally demanding. Furthermore, due to limited detailed information on the returns to alternative land uses, we have to keep our GE framework aggregate and basic. Since GDP focuses entirely on the overall economic efficiency of the economy, we complement this indicator by an index on inequality. In particular, we calculate the Gini index for each conversion ratio using GE framework outcomes of relative price changes and household income data. Finally, as both GDP and Gini indicators are aggregate, we provide insights on household welfare and distributional impacts of the optimal conversion ratio by region and socio-economic group with a micro-simulation.

The remainder of this section describes the structure of our GE framework, and the calibration and measurement of the Gini index, household welfare and distributional impacts.

3.1. GE framework: measuring real GDP

Our dynamic GE framework models an open economy with a representative household. Domestic producers are divided into three industries, with government demands, investment and international trade. The three production industries include *rice*, *non-rice* and *others* of which *rice* represents all types of rice; *non-rice* consists of other staple food, vegetables and some annual industrial crops that can be planted on rice land and vice versus¹; and *others* is made of all remaining commodities in the economy. Production uses five input factors, namely capital (K), labour (N) and three different land types for three produced goods (L^{rice} , $L^{non-rice}$ and L^{others}). At each time $t \in [1, T]$, the GE framework outcome also depends on the conversion ratio (r) and the realisation of uncertain factors (u) specified in equation (1), which we suppress here for ease of reading.

The structure of our GE framework can generally be characterized by five main sets of conditions. The first one specifies the total supply being equal to the total demand in three industries:

$$q_t^i = \sum_{s \in S} Q_t^{s,i} \quad (2)$$

for $i \in \{rice, non-rice, others\}, s \in S = \{rice, non-rice, others, H, G, I, Ex\}$

where at time t , q_t^i is the supply of industry i ; $Q_t^{s,i}$ is the demand of sector s for the output i ; Ex , H , G and I denote exports, household, government and investment sectors, respectively.

The second set of conditions are zero profit conditions in three industries:

$$w_t^i q_t^i = R^i w_t^i q_t^i + K_t^i w_t^K + N_t^i w_t^N + L_t^i w_t^{L_i} + \sum_j Q_t^{i,j} w_t^j, \quad (3)$$

$$\text{for } i \in \{rice, non-rice, others\}, j \in \{rice, non-rice, others, Im\}$$

¹Specifically, *non-rice* includes staple foods other than rice (e.g., maize, cassava, wheat, etc.), starchy and tuber crops (e.g. potatoes, sweet potatoes, taro, etc.), nuts (e.g. peanuts, sesame, etc.), vegetables (e.g. beans, cabbage, peas, etc.), flowers, fast growing fruit crops (e.g. water melon, papaya, banana, etc.) some industrial crops (sugar cane, tobacco, cotton etc.). Land for planting these crops can be used to plant rice and vice versus.

where w_t^i is the price of commodity i ; w_t^K , w_t^N and $w_t^{L^i}$ are the prices of capital, labor and three types of land; Im is imports so w_t^{Im} is the price of import which is normalized to one; R^i is the sale tax rate exogenously imposed on the production industry i ; and $Q_t^{i,j}$ is the industry i 's demand for input j .

The third set of conditions requires household expenditure to be equal to its income which includes after-tax income from production factors and government transfers:

$$y_t^H = w_t^K K_t(1 - R^K) + w_t^N N_t(1 - R^N) + \sum_i w_t^{L^i} L_t^i(1 - R^{L^i}) + y_t^{GH}, \quad (4)$$

for $i \in \{rice, non-rice, others\}$

where y_t^H is household expenditure, R^K , R^N , and R^{L^i} are the tax rates exogenously imposed on capital, labor and three types of land, respectively, and y_t^{GH} is the government transfer to households.

The fourth set of conditions implies that the total capital, labor, and land allocated to the three industries is equal to their corresponding resources available in the economy under the full employment assumption. Here we consider three constraint modelling cases. The first case is an equality-constrained condition which says that *rice* land protection is followed precisely as per the minimum threshold required by the government. The problem with this specification is that *rice* land can not be expanded even when doing so is more efficient, although an expansion is ‘allowed’ due to no restriction being imposed on converting *non-rice* land into *rice* land. This case is called “*exact protection*” and is typically specified in GE models for tractability². We specify this scenario using the following equations:

²For example, Nielsen (2003) modelled a shift of 5% rice land into other agricultural uses in Vietnam.

$$\left\{ \begin{array}{ll} \mathbb{K}_t & = \sum_i K_t^i, \quad \text{for } i \in \{rice, non-rice, others\} \\ \mathbb{N}_t & = \sum_i N_t^i, \quad \text{for } i \in \{rice, non-rice, others\} \\ \mathbb{L}^{others} & = L_t^{others} \\ \mathbb{L}^{non-rice} + \mathbb{L}^{rice}r & = L_t^{non-rice} \\ \mathbb{L}^{rice}(1 - r) & = L_t^{rice} \end{array} \right. \quad (5)$$

where the first two equations in the system (5) refer to the full employment assumption for capital and labour; the third equation implies that all available *others* land is used in *others* industry; and the last two equations say that *rice* land planted is exactly equal to its specified protected area and *non-rice* land is expanded to absorb all newly released *rice* land if any. It is worth noting that the left-hand-side in the system (5) denotes the total available resources, and the time index t is only needed in equations of capital and labour whose dynamics will be specified later in this subsection.

The second case also presents an equality-constrained condition but differs from the first case in having no restriction on crop choice between *rice* and *non-rice*. This case is typical for ALP in most countries that are concerned about food security, and want to protect land for a group of staple food which can be substituted for one another rather than protecting one particular staple. This case is called “*free crop choice*”. The full employment assumption is formalized in a similar way as in the system (5) except the last two equations being in the form:

$$\left\{ \begin{array}{ll} \mathbb{L}^{rice} + \mathbb{L}^{non-rice} & = L_t^{rice} + L_t^{non-rice} \\ (1 - R^{L_{rice}})w_t^{rice} - (1 - R^{L_{non-rice}})w_t^{non-rice} & = 0 \end{array} \right. \quad (6)$$

where $R^{L_{rice}}$ and $R^{L_{non-rice}}$ are land taxes on *rice* and *non-rice* land. In essence, equations in (6) say that *rice* and *non-rice* land is constrained by the common pool of land in these two industries, and are allocated in a manner that equalizes their rental rates.

The third case resembles the policy context in Vietnam using an inequality-constrained condition. Here, the land protected quantity is the minimum *rice* land area, and farmers can expand their rice production using more land from *non-rice* crops until the rental rates in two industries are equalized. We call this case “*minimum protection*”. We formalize this

case by changing the last two equation in the system (5) using the Kuhn-Tucker conditions as follows:

$$\begin{cases} \mathbb{L}^{rice} + \mathbb{L}^{non-rice} & = L_t^{rice} + L_t^{non-rice} \\ \mathbb{L}^{Rice}(1-r) & \leq L_t^{Rice} \\ [L^{rice} - \mathbb{L}^{rice}(1-r)][(1-R^{L_{rice}})w_t^{rice} - (1-R^{L_{non-rice}})w_t^{non-rice}] & = 0 \end{cases} \quad (7)$$

Mathematically, this case is the combination of the first and second cases.

The final set of conditions captures the dynamics of total capital and labor:

$$\mathbb{N}_{t+1} = (1+g)\mathbb{N}_t \quad \text{for } t = 0, 1, \dots, T-1 \quad (8)$$

$$\mathbb{K}_{t+1} = \mathbb{K}_t + \theta I_t - \delta \mathbb{K}_t \quad \text{for } t = 0, 1, \dots, T-1 \quad (9)$$

where g is annual working labour growth rate; I_t is real investment; θ is the transformation rate of investment into new capital; and δ is the depreciation rate of existing capital. Other conditions in our GE framework follow those in standard models (e.g. Dixon et al., 1992) and are detailed in Appendix A. Finally, GDP is calculated using the expenditure approach:

$$\text{GDP}_t = \sum_i \left[\left(Q_t^{H,i} + Q_t^{G,i} + Q_t^{I,i} + Q_t^{ex,i} \right) w_0^i \right] - w_0^{im} \sum_j Q_t^{j,im} \quad (10)$$

for $i \in \{rice, non-rice, others\}$ and $j \in \{rice, non-rice, others, H, G, I\}$.

To conclude this sub-section, it is important to note that our GE framework is simple but relevant for the policy context discussed earlier. Notably, the interaction between *rice* and *non-rice* industries is of particular significance in our search for the optimal conversion ratio r since *rice* and *non-rice* industries use similar land, but have to pay different rental rates due to government restrictions on crop choice for *rice* designated land. Such interactions are key in our GE framework, and thus land for each industry is modelled explicitly to accomodate the discrepancies in rental rates among industries. To this end, GDP changes with land reallocation across sectors which is plausible due to enhanced efficiency, thus enabling the

optimization process. This feature makes our GE framework distinct from previous GE models on Vietnam’s rice land policy despite the general consensus that a wedge in rental rates between designated rice land and other land uses exists (e.g. Rutten et al., 2014; Giesecke et al., 2013; Nielsen, 2003). Another feature that distinguishes our model from previous models is that we model an inequality-constrained case which best resembles the policy context in Vietnam in addition to the typical equality-constrained case in previous studies.

3.2. GE framework: calibration

The calibration of our GE framework broadly follows the standard method (Wing, 2004; Dawkins et al., 2001). In particular, we obtain estimates from existing studies for some parameters and use this information together with SAM to calibrate the remaining parameters, while solving for the values of endogenous variables. These parameters will be described in detail in the section on data and are subject to a sensitivity analysis, in the section on results, to check if the results of our stochastic dynamic optimization problem are robust.

Information on the transformation rate of investment into new capital (parameter θ in equation (9)) is highly important in our model given the model’s dynamic nature and our focus on GDP. However, θ is country specific, and its estimates for Vietnam are hardly available. To address this problem, we use an empirical tuning approach and calibrate this parameter so that the GDP growth in our dynamic GE closely matches the actual growth path in Vietnam. This tuning is repeated in our sensitivity analysis of model-specified parameters.

Finally, it is worth mentioning that our model calibration differs from previous studies on Vietnam’s rice land policy, despite also broadly following the standard calibration method. That is, we do not use the assumption that the economy is in equilibrium with an optimal allocation of resources as used previously (e.g. Nielsen, 2003). This assumption is apparently violated due to the government distortion in the land market, leading to discrepancies in rental rates among different land types (Markussen et al., 2011; Giesecke et al., 2013). Although Giesecke et al. (2013) mimic this situation using a phantom tax, here, we take a

step further by separating land by industry, thus allowing the rental rates being different across land types. With this model design and SAM, we hope to largely capture the extent of rental differences and their impact on GDP.

3.3. Micro-simulation: measuring changes in inequality and household welfare

Using household survey data, we measure overall inequality using the income Gini index proposed by Gini (1921) as:

$$\text{Gini}_t = \frac{\sum_{h_1=1}^n \sum_{h_2=1}^n y_t^{h_1} - y_t^{h_2}}{2n^2 \sum_{h=1}^n y_t^h}$$

where n is the household sample size; at time t for $t \in [1, T]$, Gini_t is the Gini index and y_t^h is the income of a particular household h which is different from y_t^H , the income of a representative household in the GE framework. Here y_t^h is measured as:

$$y_t^h = \sum_i q^{h,i} w_t^{h,i}$$

for $i \in \{\text{rice}, \text{non-rice}, \text{others}, \text{capital}, \text{labour}, \text{rice-land}, \text{non-rice-land}, \text{others-land}\}$

where $q^{h,i}$ denotes the net supplied quantity of commodity/factor i from household h ; and $w_t^{h,i}$ is the price of commodity i at time t faced by household h . Note that $q^{h,i}$ differs from the supply q_t^i of the whole industry i while $w_t^{h,i}$ is not exactly the same with the price w_t^i faced by the representative household in the GE framework due to regional and spatial variation in the sample. When the *rice* land conversion ratio (r) changes and uncertain factors (u) are realized, values of the endogenous variables in our GE framework, including prices and quantities supplied, change accordingly. We use the price outcome together with the data from a household survey to calculate the Gini index for each level of r and the realisation of u . Thus the percentage change in income inequality for year t , $\Delta IEQ_t(r)$, caused by the change in *rice* land policy is measured as:

$$\Delta IEQ_t(r) = \frac{\text{Gini}_t(r) - \text{Gini}_t(0)}{\text{Gini}_t(0)} \quad (11)$$

where $\text{Gini}_t(r)$ is the income Gini index when a proportion r of the current *rice* land is converted into *non-rice* land and $\text{Gini}_t(0)$ is the income Gini index when no *rice* land is converted. Here we use the income Gini index instead of an expenditure index since this index is relatively more common and is also used as the official indicator on inequality in Vietnam.

In like manner, the change in welfare is also calculated using GE price outcomes and household data. Following Deaton (1989), this change is a combination of changes in consumer and producer surpluses induced by price variations when *rice* land policy adjusts since a household (especially in rice production) can be a consumer, or a producer, or both. This approach to measuring welfare change has been applied widely in welfare analysis of food policy in the world³. Accordingly, $\Delta CS_t^{h,i}(r)$ – the change in consumer surplus in consuming commodity i of household h at time t associated with the conversion ratio r – is defined as:

$$\Delta CS_t^{h,i}(r) \cong -C^{h,i} \left[w_t^{h,i}(r) - w_t^{h,i}(0) \right] = - \underbrace{C^{h,i} w_t^{h,i}(0)}_{\text{Consumption value}} \underbrace{\frac{\Delta w_t^{h,i}}{w_t^{h,i}(0)}}_{\% \text{ change in price}} \quad (12)$$

for $i \in \{\text{rice}, \text{non-rice}, \text{others}, \text{Im}\}$

where $C^{h,i}$ is the quantity demanded and $\Delta w_t^{h,i}$ is the change in the price. We assume that consumption does not change over time to avoid aggregation problems in economic modelling. Under this assumption, $\Delta CS_t^{h,i}(r)$ is a product of its initial consumption value and the percentage change in price which comes from the GE framework and is assumed to be uniform across households.

Since the first-order approximation reflects only the immediate or short-run impact of the price change, we also consider the second-order approximation which takes into account

³See for example, Budd (1993) for Cote d'Ivoire, Barrett and Dorosh (1996) for Madagascar; and Friedman and Levinsohn (2002) for Indonesia; Valero-Gil and Valero (2008) for Mexico, Minot and Goletti (1998); Vu and Glewwe (2011); Ha et al. (2015) for Vietnam, Ivanic and Martin (2008) for developing countries, among others.

the consumer's response (or the long-term impact) in the form:

$$\Delta CS_t^{h,i}(r) \cong -C^{h,i}w_t^{h,i}(0)\frac{\Delta w_t^{h,i}}{w_t^{h,i}(0)} - 0.5\varepsilon_d^i C^{h,i}w_t^{h,i}(0)\left[\frac{\Delta w_t^{h,i}}{w_t^{h,i}(0)}\right]^2 \quad (13)$$

where ε_d^i is the own-price demand elasticity of commodity i .

Likewise, the second-order approximation of the change in producer surplus, $\Delta PS_t^{h,i}(r)$, can be calculated as follows:

$$\Delta PS_t^{h,i}(r) \cong q^{h,i}\left[w_t^i(r) - w_t^i(0)\right] \cong \underbrace{q^{h,i}w_t^{h,i}(0)}_{\text{Revenues}} \underbrace{\frac{\Delta w_t^{h,i}}{w_t^{h,i}(0)}}_{\% \text{ change in price}} + 0.5\varepsilon_s^i q^{h,i}w_t^{h,i}(0)\left[\frac{\Delta w_t^{h,i}}{w_t^{h,i}(0)}\right]^2 \quad (14)$$

for $i \in \{\text{rice}, \text{non-rice}, \text{others}, \text{Im}, \text{capital}, \text{labour}, \text{rice-land}, \text{non-rice-land}, \text{others-land}\}$

where ε_s^i is the own-price supply elasticity of commodity i .

Combining both changes in consumer and producer surplus, we use two indicators including the household net benefit, $NB_t^h(r)$, which is calculated as:

$$NB_t^h(r) = \sum_i \left[\Delta PS_t^{h,i}(r) + \Delta CS_t^{h,i}(r) \right] \quad (15)$$

for $i \in \{\text{rice}, \text{non-rice}, \text{others}, \text{Im}, \text{capital}, \text{labour}, \text{rice-land}, \text{non-rice-land}, \text{others-land}\}$

and the average of household yearly net benefit ratio during the planning horizon, $\overline{NBR_t^h(r)}$, in the form:

$$\overline{NBR_t^h(r)} = \frac{1}{T} \sum_t \frac{NB_t^h(r)}{Y^h} \quad (16)$$

for $i \in \{\text{rice}, \text{non-rice}, \text{others}, \text{Im}, \text{capital}, \text{labour}, \text{rice-land}, \text{non-rice-land}, \text{others-land}\}$

which compares the net benefit a household gains/looses each year against its initial wealth, proxied by its initial expenditure Y^h .

Since households gain/lose over the whole planning horizon, following the usual practice in finance, we calculate changes in household consumer and producer surpluses and net benefit as annualized values⁴. Finally, for brevity, we only present results using the optimal conversion ratio r^{optimal} obtained from our dynamic optimization in the *minimum protection* case.

4. Model parameterization and data

For the stochastic dynamic optimization model, information on the annual discount factor and distribution of stochastic noise is needed. For the former, we estimate ρ as the real interest rate in Vietnam using the average of the difference between the government bond rate which represents the nominal interest rate, and the consumer price index, which approximates the inflation rate in Vietnam, during the period 2007-2015 (IMF, 2017). For the latter, we focus on the volatilities caused by Vietnam's rice yield and the world demand for Vietnamese rice since they are random (e.g., due to good/bad weather) and have a large impact on rice production and prices in Vietnam. An example of this shock is when Vietnam experiences good weather in a particular year, resulting in a higher rice yield, more rice output and exports to the world. Concurrently, other key rice exporters-countries in Asia would likely enjoy good weather as well. Under this circumstance, there would be much higher rice supply in the world, leading to less demand for Vietnamese rice. Therefore, Vietnam's rice exports and domestic prices would eventually fall in that year. Put differently, there are two primary sources of volatilities in place which are highly correlated. They are modelled as noise which have variances and covariance of Vietnam and world rice yield data during 2003-2013 (IRRI, 2016), added to the TFP trend in domestic rice production and the shift parameter in the export demand for Vietnam's rice.

Regarding the GE framework, we need a suitable SAM table and values for model-specified parameters. The SAM table (Table 1) is compiled based on the 2011 SAM for

⁴In particular, we multiply each net present values of the streams of surpluses and net benefits with $(1 - \kappa)/[\kappa(1 - \kappa^T)]$ where $\kappa = \frac{1}{1 + \rho}$.

Vietnam constructed by CIEM-WIDER (2014), while model-specified parameters including CES coefficients for production and consumption functions, price elasticities of exports, annual depreciation of capital and growth of labour are presented in Table 2. The model-specified parameters are largely estimated using recent data for Vietnam in a series of students' research master essays under direct supervision of one co-author (and available upon request), with the remaining drawn from the literature. The annual depreciation of capital (equation 9) is 10% as per Decision 1940-QD-BTC issued by Vietnam's Ministry of Finance (MOF, 2015). Finally, annual labour force growth (equation 8) is 1% to take into account both the past average growth of 1.7% during 2010-2014 in Vietnam (General Statistic Office, 2016b) and the population growth forecasted for Vietnam to decrease from 1% in 2017 to 0.6% in 2027 (FAO, 2017).

Microsimulation requires information on demand and supply elasticities (Appendix B) and household data. For the former, there are quite a few estimates for demand elasticities for rice and food commodities which vary across studies due to sample variation and different estimation methods (Vu, 2008; Le, 2008; Benjamin and Brandt, 2004; Minot and Goletti, 2000). We choose the Marshallian own-price elasticity estimates by Vu (2008) since the author uses the most updated data (VHLSS 2006)⁵, corrects for both quality and measurement error problems which are common in household data, and are available by quintile, urban/rural and by region. Furthermore, his estimates for rice and staples are suitable for *rice* and *non-rice* in our paper. Since estimates for *others* are not available for Vietnam, we use the average, weighted by the expenditure share, of the demand elasticity estimates by Vu (2008) for all other food groups rather than rice and staples. While this estimate may not be precise since *others* include both food other than rice and staples, and non-food, it would not substantially affect our results because the price changes for *others* are expected to be small given resources are being reallocated mainly between *rice* and *non-rice* sectors.

⁵Except for (Le, 2008), all other studies use data collected in 1990s which do not reflect the changing diet of Vietnamese as income has increased considerably even since.

Table 1: 2011 Social accounting matrix for Vietnam (million USD in 2011 price)

	<i>rice</i>	<i>non-rice</i>	<i>others</i>	Capital	Labor	<i>rice</i> land	<i>non-rice</i> land	<i>others</i> land	H'holds	Gov't	Inv'ment	Export	Total
<i>rice</i>	2200	25	3177						4888			3119	13407
<i>non-rice</i>	584	210	2140						797			532	4261
<i>others</i>	1875	669	141657						72094	7428	27982	107485	359189
Capital	556	183	50815										51553
Labor	4153	884	64903										69940
<i>rice</i> land	2551	0	0										2551
<i>non-rice</i> land	0	1799	0										1799
<i>others</i> land	0	0	5596										5596
Households				38665	69940	2449	1709	5209		15047			133018
Government	161	36	18326	12888		102	90	387	3794				35784
Saving									13375	12172		2435	27982
Import	1328	458	72576						38071	1137			113570
Total	13407	4261	359189	51553	69940	2551	1799	5596	133018	35784	27982	113570	

Source: compiled based on CIEM-WIDER (2014) and (General Statistic Office, 2016b)

Table 2: Model-specified parameters in the GE framework

Parameter description	Notation	Baseline value	Sources	Ranges for sensitivity analysis
CES coefficient for <i>rice</i> production	σ^{rice}	0.45	Hoang (2015)	[0.35,0.55]
CES coefficient for <i>non-rice</i> production	$\sigma^{non-rice}$	0.45	Hoang (2015)	[0.35,0.55]
CES coefficient for <i>others</i> production	σ^{others}	1	Gabriel and Daniel (2014)	[0.7,1.3]
Price elasticity coefficient of <i>rice</i> exports	ε^{rice}	-0.75	Chowdhury (2015)	[-0.95,-0.55]
Price elasticity coefficient of <i>non-rice</i> exports	$\varepsilon^{non-rice}$	-0.7	Dang (2015)	[-0.9,-0.5]
Price elasticity coefficient of <i>others</i> exports	ε^{others}	-0.5	Pham and Nguyen (2013)	[-0.6,-0.4]
CES coefficient measuring the substitutability in consumption between necessity and non-necessity goods	σ^H	0.05	Hoang and Meyers (2015)	[0.02,0.08]
Annual capital depreciation rate	δ	10%	MOF (2015)	[5%,15%]
Annual labor force growth rate	g	1%	General Statistic Office (2016b); FAO (2017)	[0.7%,1.3%]
Annual discount rate	ρ	3%	IMF (2017)	[2%,4%]

Estimates of supply elasticities are available for *rice* and *non-rice* only (Khiem and Pingali, 1995). We assume that household supply elasticity for *others* is zero since households would not likely produce these goods. Meanwhile, labour supply elasticity is 0.46 (Domeij and Floden, 2006) while supply elasticities for other factors are assumed to be zero.

Household data come from VHLSS 2010, a nationally representative household survey. Although there are more updated versions of this data, we choose this survey since it was collected in a similar period to our SAM table. The data have 9,399 households interviewed on both income and expenditure. Finally, all values are reported in USD in 2011 prices using the exchange rate of 1USD = 20,000 VND unless otherwise specified.

5. Results

Our aggregate results are obtained using Matlab, version 2014b, while our microsimulation is done using R, version 3.3.2. For each set of parameter values in the baseline, or in the range for checking the robustness of the aggregate result, empirical tuning is performed to find a suitable value of θ so that the GDP growth in our dynamic GE model closely matches the actual growth path in Vietnam. Once the value of a fitted θ is found, we simulate 1000 times for the whole 10-year planning horizon, so each year has 100 realisations of the stochastic term for each level of *rice* land conversion. The step in our search for the optimal land conversion ratio r is single one-percentage point. To this end, solving the model and checking its robustness involves roughly 600,000 runs in total, not to mention the runs for empirical tuning to find θ . Statistics in the microsimulation are also calculated using data from the runs for the optimal conversion ratio.

5.1. Optimal rice land conversion ratio

Figure 1 presents the total change in real GDP over 10 years associated with various *rice* land conversion ratios. All three constraint modelling cases suggest that the gain is about 2.3 billion \$US when roughly 13% of *rice* land is converted into *non-rice* area. The gain in GDP is expected since resources are allocated in a more efficient way when the economy is moving from a suboptimal to an optimal allocation of land between *rice* and *non-rice* sectors, and land rental rates in these two sectors become equalized. The initial wedge in the rental rates or the inefficient allocation of land resources is evident in the SAM table with the rental rate of *non-rice* land being about USD 701/planted ha, twice as much as that of *rice* land being only USD 333/planted ha⁶.

Nonetheless, the relationship between the real GDP gain and *rice* land conversion ratio varies substantially across different constraint modelling cases despite their consensus at the maximum. For example, GDP gains remain the same beyond the optimal conversion ratio in

⁶That is, the total rental costs for *rice* and *non-rice* land are USD 2,551 million and USD 1,799 million as shown in Table 1, columns 2 and 3, respectively, for a total 7.655 million planted ha of *rice* land and 2.378 planted ha of *non-rice* land (General Statistic Office, 2016b).

Figure 1: Land rice conversion and real GDP change

Minimum Protection but stays constant at the maximum throughout the whole range of the *rice* land conversion ratio in *Free Crop Choice* (Figure 1, panel (a)). Meanwhile, in *Exact Protection* case, the GDP gain is hump-shaped; that is, further increasing the conversion ratio beyond the optimal point results in a monotonic fall in GDP (Figure 1, panel (b)).

This difference across modelling cases is surprising at first, but turns out to be sensible for two reasons. First, real GDP is improved in *Free Crop Choice* due to no constraints imposed to prevent resources from being allocated optimally, so the economy moves right to the optimal allocation of resources. Since farmers can always choose to plant *rice* or *non-rice* crop in this case, GDP gains are not affected by *rice* the land conversion ratio. Second, the monotonic fall of GDP beyond the optimal point in *Exact Protection* is caused by the fact that farmers are modelled to follow exactly the land conversion ratio set by the government instead of treating it as a minimum as actually required. For example, suppose the government allows 15%, at most, of the *rice* land to be converted into *non-rice* land while market general equilibrium prices suggest that only 13% of the *rice* land is needed for *non-rice* sector. In this circumstance, as farmers can convert 15% or less *rice* land into *non-rice*, they will choose the optimal ratio of 13% instead 15% to maximize their profit. This behaviour is modelled in *Minimum Protection*, leading to the stark difference in its outcome

compared with that in *Exact Protection* in situations when government's land conversion threshold is higher than the optimal *rice* land conversion ratio. Put differently, *Minimum Protection* takes into account the optimal behaviour of farmers when the land use constraint imposed by the government is no longer binding while *Exact Protection* does not. The difference in outcomes by the three constraint modelling cases highlights the importance of modelling as closely as possible the policy context to avoid misleading results.

5.2. Impact on inequality

Figure 2 presents changes in overall equality in the three different constraint modelling cases. In *Free Crop Choice*, equality improved, though marginally, by 0.15% regardless of *rice* land conversion ratio. This result makes sense since the Gini index is income-based, and farmers, especially rice farmers, would be better off with free crop choice, narrowing the rural-urban income gap. Meanwhile, in *Minimum Protection*, the Gini index reduces gradually as the *rice* land conversion ratio approaches to the optimal level and then levels off (at the same level as in *Free Crop Choice*), when farmers can no longer increase their income. In contrast, inequality monotonically decreases as more *rice* land is converted into *non-rice* land in *Exact Protection*. This result is counter-intuitive, and, again, solely driven by the assumption that farmers follow precisely government policy on *rice* land allocation instead of behaving optimally. Indeed, beyond the optimal point, too little land is allocated to *rice* production, pushing up *rice* price against *non-rice* price. Incomes of rural households, most of whom have rice production as their primary source of income, will increase while that of urban households and non-farm (richer) rural households remains relatively unchanged, resulting in a monotonic decrease in inequality.

To sum up, if farmers have more crop choice, overall equality would likely improve, though slightly; albeit attention needs to be paid to the way constraints are modelled since results can be very much in error when constraints are non-binding.

5.3. Impact on household welfare

Unlike the Gini coefficient, NB and $\overline{NBR}$ look at the gain/loss in both consumption and income of a household. Results of the optimal rice land conversion policy are presented

Figure 2: Land rice conversion and change in Gini index

in Table 3. Since at an optimum point, outcomes are quite similar across three modelling cases, we focus on *Minimum Protection*. Households are classified based on their geographical region, urban-rural and wealth ranking status (columns 1-2). We define households as a net seller/net buyer/self-sufficient if their rice consumption value is smaller/larger than, or equal to their rice production value (columns 3-5). It can be seen that rice production is a rural activity with most rice net sellers being rural households, and rich households are less likely involved in rice production. Across regions, households in Central Highlands (CH) and South East (SE) are more likely to buy rice since the former has soil and climate conditions more suitable for crops such as coffee, cashew nuts, maize, etc., while the latter is the largest economic and manufacturing hub in Vietnam. Meanwhile, the Mekong River Delta (MRD) has as much as 70% of households being net buyers despite producing over 50% of rice in Vietnam, all caused by large-scale production in this region compared to others.

The short-run or immediate impact of the price change are presented in columns 6–9 while the long-run impact is in columns 10-13. There is little sensitivity between the two sets of results, and therefore, we only discuss the long-run impact. Most statistics are statistically significant at 1% level except for some changes in producer surplus for an average urban, rural and national households.

Table 3: Household net position in rice, changes in annualized consumer surplus and producer surplus, net benefit (USD/per person) and average net benefit ratio (%) over the planning horizon

Group	% of all hh	% of household			Short-run impact				Long-run impact			
		Net Seller	Self sufficient	Net Buyer	Δ CS	Δ PS	NB	Benefit Ratio	Δ CS	Δ PS	NB	Benefit Ratio
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
All	100	33.8	0.4	65.8	2.0 ^a [0.000]	0.2 [0.2]	2.2 ^a [0.000]	0.01 ^a [0.000]	2.3 ^a [0.000]	0.2 [0.2]	2.5 ^a [0.000]	0.1 ^a [0.000]
Urban	30.5	8.1	1.0	90.9	3.6 ^a [0.1]	-0.2 [0.3]	3.4 ^a [0.3]	0.2 ^a [0.000]	3.9 ^a [0.1]	-0.2 [0.3]	3.7 ^a [0.3]	0.3 ^a [0.000]
Rural	69.5	45.0	0.2	54.8	1.2 ^a [0.05]	0.4 ^b [0.2]	1.6 ^a [0.2]	-0.1 ^a [0.000]	1.6 ^a [0.1]	0.4 ^b [0.2]	2.0 ^a [0.2]	-0.03 ^a [0.000]
RRD	24.8	47.0	0.0	53.0	2.1 ^a [0.000]	1.9 ^a [0.03]	4.0 ^a [0.000]	0.5 ^a [0.000]	2.4 ^a [0.000]	2.0 ^a [0.03]	4.4 ^a [0.000]	0.6 ^a [0.000]
MNM	12.6	47.5	0.2	52.3	-0.1 ^a [0.000]	-5.2 ^a [0.04]	-5.4 ^a [0.000]	-1.7 ^a [0.000]	0.2 ^a [0.000]	-5.2 ^a [0.04]	-5.0 ^a [0.000]	-1.6 ^a [0.000]
NCC	21.7	40.5	0.0	59.5	1.5 ^a [0.000]	-2.6 ^a [0.1]	-1.2 ^a [0.000]	-0.4 ^a [0.000]	1.8 ^a [0.000]	-2.6 ^a [0.1]	-0.8 ^a [0.000]	-0.4 ^a [0.000]
CH	5.4	19.5	0.3	80.2	1.0 ^a [0.000]	-9.1 ^a [0.05]	-8.1 ^a [0.001]	-2.3 ^a [0.001]	1.3 ^a [0.000]	-9.1 ^a [0.05]	-7.8 ^a [0.001]	-2.2 ^a [0.001]
SE	16.8	3.9	1.9	94.2	3.7 ^a [0.000]	-2.8 ^a [0.1]	0.9 ^a [0.000]	-0.01 ^a [0.000]	4.0 ^a [0.000]	-2.8 ^a [0.1]	1.2 ^a [0.000]	0.02 ^a [0.000]
MRD	18.8	30.1	0.3	69.6	2.5 ^a [0.000]	10.2 ^a [0.1]	12.7 ^a [0.000]	1.6 ^a [0.001]	2.9 ^a [0.000]	10.2 ^a [0.1]	13.2 ^a [0.000]	1.7 ^a [0.001]
Poorest	8.0	45.8	0.2	54.0	-0.8 ^a [0.000]	-3.2 ^a [0.02]	-4.0 ^a [0.000]	-2.0 ^a [0.001]	-0.6 ^a [0.000]	-3.2 ^a [0.02]	-3.7 ^a [0.000]	-1.9 ^a [0.001]
2nd	9.2	42.8	0.2	57.0	-0.4 ^a [0.000]	-2.4 ^a [0.02]	-2.7 ^a [0.000]	-0.8 ^a [0.000]	-0.1 ^a [0.000]	-2.3 ^a [0.02]	-2.4 ^a [0.000]	-0.7 ^a [0.000]
3rd	9.1	48.7	0.1	51.2	0.1 ^a [0.000]	-1.7 ^a [0.04]	-1.6 ^a [0.000]	-0.4 ^a [0.001]	0.4 ^a [0.000]	-1.6 ^a [0.04]	-1.3 ^a [0.000]	-0.3 ^a [0.001]
4th	9.7	48.5	0.0	51.5	0.6 ^a [0.000]	0.8 ^a [0.04]	1.3 ^a [0.000]	0.3 ^a [0.000]	0.9 ^a [0.000]	0.8 ^a [0.04]	1.6 ^a [0.000]	0.3 ^a [0.000]
5th	9.8	43.4	0.1	56.5	1.0 ^a [0.000]	0.7 ^a [0.05]	1.7 ^a [0.000]	0.3 ^a [0.000]	1.3 ^a [0.000]	0.7 ^a [0.05]	2.0 ^a [0.000]	0.3 ^a [0.000]
6th	10.0	40.3	0.6	59.1	1.5 ^a [0.000]	1.4 ^a [0.05]	2.9 ^a [0.000]	0.4 ^a [0.000]	1.8 ^a [0.000]	1.4 ^a [0.05]	3.2 ^a [0.000]	0.5 ^a [0.000]
7th	10.7	31.1	0.3	68.6	1.9 ^a [0.000]	0.6 ^a [0.1]	2.5 ^a [0.000]	0.3 ^a [0.000]	2.3 ^a [0.000]	0.6 ^a [0.1]	2.8 ^a [0.000]	0.4 ^a [0.000]
8th	10.8	27.9	0.2	71.9	2.7 ^a [0.000]	3.1 ^a [0.1]	5.9 ^a [0.000]	0.6 ^a [0.000]	3.1 ^a [0.000]	3.2 ^a [0.1]	6.2 ^a [0.000]	0.6 ^a [0.000]
9th	11.0	16.1	0.4	83.5	3.9 ^a [0.000]	2.4 ^a [0.1]	6.2 ^a [0.000]	0.5 ^a [0.000]	4.3 ^a [0.000]	2.4 ^a [0.1]	6.6 ^a [0.000]	0.5 ^a [0.000]
Richest	11.7	5.3	1.7	93.0	7.0 ^a [0.000]	-0.9 ^a [0.1]	6.1 ^a [0.000]	0.3 ^a [0.000]	7.5 ^a [0.000]	-0.9 ^a [0.1]	6.5 ^a [0.000]	0.3 ^a [0.000]

Notes: Δ = Change; CS=Consumer Surplus; PS = Producer Surplus; NB=Net Benefit; CS, PS and NB are annualized values; RRD=Red River Delta, MNM=Midlands and Northern Mountains, NCC=Northern and Coastal Central, CH=Central Highlands, SE=South East, MRD=Mekong River Delta. Standard errors are in square brackets. All statistics are calculated taking into account the VHLSS 2010 sampling design. (a) $p < 0.01$, (b) $p < 0.05$, (c) $p < 0.10$.

Overall, the optimal rice land conversion policy results in an increase of 2.5 USD in NB per person (column 12). Taking Vietnam’s population of about 90 million people as a whole, the country NB is expected to increase by about 225 million USD. Urban dwellers gain 3.7 USD in NB per person, about double that of their rural counterparts. The positive impact on NB is largely driven by the gain in consumer surplus. This finding suggests that shifting away from rice to consuming more products in *non-rice* such as vegetables, fast-growing fruits, nuts, sugar, starchy and tuber crops, etc., imply that urban and rich consumers are likely better off when *rice* price increases and prices of *non-rice* fall. Furthermore, the modest gain from producer surplus of rural households indicates that rice production no longer plays a principal role in rural household activities, as it once did.

Turning to the average net benefit ratio $\overline{NBR}$, the impact is negligible at the country level, being 0.1% (column 13). Nonetheless, urban households gain while rural ones loose, though the magnitude is tiny. Note that all $\overline{NBR}$ and NB estimates are of the same sign in our results except for rural households. This difference in sign is possible, and in this case, it is due to significant variation in the sample, which we will discuss shortly, and the fact that $\overline{NBR}$ and NB measure closely related but different things.

Among six regions, MRD and, to a lesser extent, the Red River Delta (RRD) stand out as ‘winners’. Only in these two regions do both consumers and producers benefit. In others, in contrast, consumers gain, but producers lose (columns 10-13). This result is similar to the one by Minot and Goletti (1998, table 1) who find that the impact of the trade liberalization also increases rice prices, with benefit to MRD and RRD. This similarity, together with the fact that we are using a more updated household dataset, corroborates a persistent pattern in the regional distribution of rice production and consumption in Vietnam. In particular, CH and Midlands and Northern Mountains (MNM) are the worst off, especially with regard to producer surplus (column 11), due to having soil largely suitable for *non-rice*. A 13% conversion of *rice* land into *non-rice* implies an increase of about 40% of total planted area for *non-rice*, which results in an increase in the supply of this sector. As a result, there is a massive fall in prices of *non-rice*, causing losses to its producers. Meanwhile, these two

regions have the highest proportions of poor households, whose diet is dominated by rice, so consumer gains here are the lowest (column 10). On the contrary, SE, followed by MRD and RRD, enjoy the highest gain in consumer surplus due to their being the richest regions in the country.

Further disaggregated results by wealth decile reveal a pro-rich pattern of this rice land conversion policy. In column 10, a clear trend can be seen that richer households gain more consumer surplus than poorer ones. This trend points out an inevitable shift away from the heavy consumption of rice as the nation becomes richer, as found in other countries (Shoichi Ito, 1989). Regarding producer surplus, there exists no clear pattern, but it is evident that the poorest 30% households experience the largest losses. Coupled with their modest gain in consumer surplus, these groups are the biggest losers should this policy be implemented. The reason is clear. Likely living in difficult terrains, their primary source of income comes from maize, cassava, etc., while rice remains crucial in their diet. The reallocation of rice land which results in higher *rice* prices and lower *non-rice* prices, harms these households on both fronts.

5.4. Sensitivity analysis

We check whether our optimization model outcome is sensitive to its parameter values. Table 2 specifies the range of values for sensitivity analysis which is drawn either from the upper and lower bounds of the parameter estimates in the literature, or we vary them by $\pm 30\%$ to $\pm 50\%$. The model outcomes are presented in Figure 3 obtained when we change each parameter value at a time while keeping others at their baseline values. It can be seen that the optimal conversion ratio is hardly sensitive to most of the parameter values except the CES coefficients of *rice* and *non-rice* and, to a less extent, the price elasticity coefficient of *others* exports. This result is plausible for two reasons. First, since the policy shock to the ‘business-as-usual’ scenario is the reallocation of land between *rice* and *non-rice* sectors, their production function parameters are expected to be key to the model outcome. Second, although *rice* and *non-rice* are essential for household living standards, especially in rural areas, their combined export value is than 10% of total exports revenues in Vietnam (General

Statistic Office, 2016a). Therefore, the capacity to export *others* might have some influence on land allocation in the other two sectors in the GE framework.

Figure 3: Sensitivity analysis of the optimal conversion rate

6. Discussion

This paper contributes to the literature on ALP by presenting the first attempt, to the best of our knowledge, to quantify how much land should be preserved for a particular crop. ALP has long been implemented for food security concerns in many countries but hardly justified using an optimization framework. This lack of policy guidance likely results in a sub-optimal outcome for the economy, as commonly found in existing literature.

Using the case of Vietnam where rice is a political and highly protected commodity, we investigate how much *rice* land should be released for use for other agricultural crops. While land policies tend to have multiple goals, we only focus on its economic efficiency measured by changes in GDP. Given Vietnam's declaration to develop a socialist-oriented market economy, we also investigate the implications of the optimal policy outcome on inequality and wealth distribution by region, urban, rural and wealth-rank status.

6.1. Policy implications

Relatively robust to parameter values, we find that about one million hectares of planted rice land, or 13% of the existing planted rice land, should be released to other crops for an optimal efficiency gain. This gain is about 2.3 billion dollars in real GDP over the planning horizon of 10 years, with a slight overall reduction in income-based inequality by 0.15%. Nonetheless, considering the policy impact on both income and consumption, the pattern is pro-rich. Indeed, as much as 30% of the poorest households, who likely live in the much less developed mountainous and highland regions of MNM and CH, are negatively affected by this optimal policy. Since poverty tends to be chronic and persistent in these two regions, due to having difficult terrains and poor infrastructure, and Vietnam generally lacks effective social safety networks due to its low level of development, this outcome presents a challenge for decision-makers in Vietnam.

6.2. Contributions, limitations and future works

Existing economic literature on ALP largely focuses on the its welfare and efficiency impact or the amount of farmland lost. While providing useful insights, they provide little guidance to answer the question “how much land should be protected?” for policy-makers. We contribute to this knowledge gap by proposing the use of an optimization model built on top of a GE framework to find the best land allocation/protection that maximizes the economy’s GDP. This aggregate analysis is supplemented by microsimulations to shed light on changes in inequality and distributional welfare impacts. To this end, our framework provides useful evidence to guide policy-making, rather than the practice of simply setting agricultural land aside in an arbitrary fashion.

Although being applied to rice land protection against other crops in Vietnam, our model is applicable to many land planning contexts. For example, it can be used to protect the production of a group of agricultural commodities versus other products, or to balance between pressures on agricultural land conversion driven by population increases and urbanization versus concerns over food security, environmental issues and uncertainty. In these situations, finding the optimal protection level or the right balance often requires a tool that can help

evaluate economy-wide macro and micro impacts of different policy parameter values with a well-defined objective function. Indeed, one may expand our objective function beyond real GDP to include other economic, social and possibly environmental indicators of interest, weighted by policy-makers to reflect their priority.

Admittedly, our model remains quite basic because of the computational challenge in optimizing over a GE framework and the practical constraints in data. A significant improvement in this work (if and when better data and computational capacity is available) would be to account for a multi-dimensional policy space. For example, policy-makers may be interested in protecting agricultural land by combining involuntary zoning and complementary tax incentives for owners. In this case, policy parameters include both the quantities of zoning and the extent of tax incentives. Furthermore, the model can be extended to take into account spatial heterogeneity to determine optimal land protection at a more disaggregated level, to balance, for example, agricultural land preservation not only at a national level but also in each sub-region.

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Appendix A: Equations in the GE framework

The main conditions of our GE framework have been described in the Methodology section. Here, we provide only details on other conditions which are standard in GE models (e.g., see Dixon et al., 1992). Specifically, producers in our GE framework minimize their costs so that their input demands are derived by minimising the level of inputs required to produce a certain amount of quantity, as a function of output prices and production quantities, or:

$$[Q_t^i, F_t^i] = \operatorname{argmin}\{[w_t^Q]'Q_t^i + [w_t^{F^i}]'F_t^i\} \quad \text{subject to } f^i(Q_t^i, F_t^i) = q_t^i \quad (17)$$

where $i \in \{rice, non-rice, others\}$, $Q_t^i \equiv [Q_t^{i,Rice}, Q_t^{i,Non-rice}, Q_t^{i,Others}, Q_t^{i,im}]'$ and $F_t^i \equiv [K_t^i, N_t^i, L_t^i]'$ are quantities demanded for intermediate commodities, imports, and primary factors; $w_t^Q \equiv [w_t^{Rice}, w_t^{NonRice}, w_t^{Others}, w_t^{im}]'$ and $w_t^{F^i} \equiv [w_t^K, w_t^N, w_t^L]'$ are prices; and q_t^i and f^i are the production (supply) quantity and function for industry i , respectively.

Producers in our model use a Constant Elasticity of Substitution (CES) technology so that their production function is of the form:

$$q_t^i \equiv f^i(Q_t^i, F_t^i) = A^i \left([\alpha^i]'[Q_t^i]^{(\sigma^i-1)/\sigma^i} + [\beta^i]'[F_t^i]^{(\sigma^i-1)/\sigma^i} \right)^{\sigma^i/(\sigma^i-1)} \quad (18)$$

where $i \in \{rice, non-rice, others\}$; parameters α^i and β^i are the 4×1 and 3×1 coefficient vectors, respectively, for the inputs; A^i is a scalar parameter, representing an industry total factor productivity (TFP) which can be always be normalized such that $\sum \alpha^i + \sum \beta^i = 1$ without the loss of generality; and σ^i is a scalar CES coefficient.

Households demand goods in a way that maximizes their utility given their budget constraint. We use a double-layered utility function to model the household demand to accommodate the substantial difference in price elasticities and substitutability between *rice* and *non-rice* on one hand, and *others* and *imports* on the other. Accordingly, the top layer of the household demand is in the form:

$$Q_t^H = \operatorname{argmax} \left[\alpha^H v_1^{(\sigma^H-1)/\sigma^H} + (1 - \alpha^H) v_2^{(\sigma^H-1)/\sigma^H} \right]^{\sigma^H/(\sigma^H-1)} \quad (19)$$

subject to $[w_t^Q]'Q_t^H = y_t^H(1 - s^{HG} - s^{HS})$

where $Q_t^H \equiv [Q_t^{H,rice}, Q_t^{H,non-rice}, Q_t^{H,others}, Q_t^{H,im}]'$; y_t^H is the household income defined in the Methodology section, while s^{HG} and s^{HS} are respective share parameters of income that households spend on government services and savings; and σ^H is a CES coefficient parameter

measuring the substitutability between the necessity and non-necessity composite goods. On the second layer, following Dixon and Rimmer (2005), $v_1 = (Q_t^{H, \text{rice}} - h^{\text{rice}} N_t)^{\beta^H} (Q_t^{H, \text{non-rice}} - h^{\text{non-rice}} N_t)^{1-\beta^H}$ is a composite necessity good with a Stone-Geary utility functional form. This composite good includes *rice* and *non-rice* with respective share parameters, β^H and $1 - \beta^H$ while N_t is the population at t . Likewise, $v_2 = (Q_t^{H, \text{others}} - h^{\text{others}} N_t)^{\gamma^H} (Q_t^{H, \text{im}} - h^{\text{im}} N_t)^{1-\gamma^H}$ is a composite non-necessity good which include *others* and *imports* with the respective share parameters, γ^H and $1 - \gamma^H$.

To model real investment, we use the Solow growth model approach and specify investment as a fixed proportion of real GDP. The rationale behind this approach is twofold. First, total investment in Vietnam has been roughly a fixed proportion of total GDP since the early 2000s (World Bank, 2008; General Statistic Office, 2011, 2016b). Second, although the other two relevant approaches, recursive dynamics and perfect foresight dynamics, would be more appropriate, allowing investment to respond not only to income but also to interest rates and other factors, they need information at a particular point in time as the boundary conditions which are not available in most cases. The most common way to circumvent this problem is to pick a steady state and assume the economy would converge to it after an extended period, generally more than 50 years. In our situation, the practical planning time horizon is ten years, being in line with the planning cycle in Vietnam, which is too short for more elaborate assumptions to hold. We also do not have any reliable information on boundary conditions in the distant future. As a result, the Solow growth model approach best suits our case.

Demand for exports of a domestic commodity i is a function with constant elasticity with respect to the relative price of domestic commodities in terms of imported goods:

$$Q_t^{i, ex} = E^i \left(\frac{w_t^i}{w_t^{im}} \right)^{\varepsilon^i} \quad (20)$$

where $i \in \{\text{rice}, \text{non-rice}, \text{others}\}$, E^i is a price-shift non-negative parameter, and ε^i is a non-positive model-specified elasticity parameter.

At the country level, government revenues come from three sources including household spending on government services, factor income taxes imposed on capital, labor, and three types of land, and sales tax, so that:

$$y_t^G = s^{HG} y_t^H + R^K w_t^K K_t + R^N w_t^N K_t + \sum_i \left\{ R^{L^i} w_t^{L^i} L_t^i + R^i w_t^i q_t^i \right\} \quad (21)$$

for $i \in \{\text{Rice, Non-rice, Others}\}$, y_t^G is the government revenues, and other notations are as defined previously or in the Methodology section. The government uses its revenues to finance its expenditure, which is assumed to remain constant, and provide government transfers to households, which is taken a fixed proportion of government spending.

Appendix B: Demand and Supply Elasticity Estimates

Group	Demand Elasticity ^(a)			Demand Elasticity ^(b)		
	<i>Rice</i>	<i>Non-rice</i>	<i>Others</i>	<i>Rice</i>	<i>Non-rice</i>	<i>Others</i> ^(c)
All	-0.80	-0.75	-1.11			
Urban	-0.72	-0.76	-1.20			
Rural	-0.82	-0.74	-1.06			
Red River Delta	-0.80	-0.85	-1.03	0.21	0.03	0.00
Midlands & Northern Mountains	-0.80	-0.85	-0.98	0.21	0.02	0.00
Northern & Coastal Central	-0.90	-0.69	-0.99	0.21	0.03	0.00
Central Highlands	-0.81	-0.70	-1.19	0.09	0.00	0.00
South East	-0.81	-0.70	-1.27	0.09	0.00	0.00
Mekong River Delta	-0.81	-0.70	-1.34	0.09	0.01	0.00
Poorest	-0.89	-0.91	-1.02			
2nd	-0.89	-0.91	-1.02			
3rd	-0.87	-0.64	-1.03			
4th	-0.87	-0.64	-1.03			
5th	-0.84	-0.77	-1.06			
6th	-0.84	-0.77	-1.06			
7th	-0.83	-0.66	-1.11			
8th	-0.83	-0.66	-1.11			
9th	-0.82	-0.70	-1.21			
Richest	-0.82	-0.70	-1.21			

Notes: Household supply elasticities of different land types and capital are assumed to be zero; labour supply elasticities are 0.46 (Domeij and Floden, 2006).

^(a): Vu (2008). Estimates for *others* are the average of nine major food groups including pork, poultry, other meat, fish, vegetables, fruits, other food items, drinks and eating out, weighted by their shares in the household food expenditure;

^(b): Khiem and Pingali (1995). Estimates for *non-rice* are the average of those for maize, cassava and sweet potatoes, weighted by their regional share in the total planted land.

^(c): Our assumption.