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Research article

Rice land protection in a transitional economy: The case of Vietnam

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ABSTRACT

Agricultural land protection (ALP) is a standard policy response to a desire for food security. However, ALP may result in a misallocation of resources. Examining rice land policy in Vietnam, we determine the optimal level of rice land protected against other crops using a stochastic optimization model built on top of a general equilibrium framework, combined with sequential micro-simulations on household data. We find that converting part of protected rice land enhances economic efficiency. Nonetheless, the policy is relatively pro-rich, implying a trade-off between poverty reduction and economic efficiency, making some households in already poor areas worse off. Our approach can be applied to land-use planning generally, highlighting the relevant tradeoffs and the search for needed optimal land-use policies.

1. Introduction

Agricultural land protection (ALP) is employed 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 farmland protection 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). In parallel, increasingly more studies measure how much farmland has been lost (e.g. Pandey and Seto, 2015; Gibson et al., 2015). Yet 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. Why is it the case?

Answering the question 'how much farmland to protect?' poses several challenges. First, a general equilibrium (GE) framework must be used to simulate the economy-wide impact of land allocation. GE analysis is data-demanding, and in this context, at the least, it requires information on returns to alternative land uses which is generally not

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available. Second, there is a need to compare different scenarios of farmland protection to know how much farmland to protect. Moreover, uncertainty should also be considered since the policy impact of land allocation may not be realized immediately, thus further complicating the task. Finally, policy objectives can be controversial and may not be well-defined, making it hard to set up an optimization problem for the question of interest.

In this light, our aim is to address some of these challenges. First, we embed a GE framework in an optimisation routine that helps evaluate not only one, but multiple policy alternatives. Therefore, we can determine the optimal level of farmland protection. Second, we control for possible uncertainty that might influence the outcome of policy scenarios such as unanticipated changes in commodity demand or productivity which is partly influenced by weather conditions. Third, we undertake a sensitivity analysis, in which we vary parameter values to ensure that our results are robust. To this end, we compare roughly 1.6 million GE scenarios in total.

To overcome the challenges in computation and data demands, our GE framework is formulated as basic, but detailed enough to answer the question of interest. Furthermore, to accommodate the possible multiple purposes of farmland protection, we combine our country-level analysis with a sequential micro-simulation using household data to provide distributional implications of the best policy option. Although each of the techniques, including stochastic optimization, GE and micro-simulation, are not new, the combination of them is quite novel. To the best of our knowledge, we are not aware of any study that applies this sort of combination before.

We use Vietnam as a case study. The choice of this case is made for three 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, should reduce uncertainty over rice supplies; while an arbitrarily set scale of rice land protection and frequent adjustments in the policy, together with a politically-driven industrial structure (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 (Ha et al., 2015). Finally, the lesson from Vietnam is relevant for many developing countries since 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 incomes increase (Thang and Popkin, 2004; Mishra and Ray, 2009; Kompas et al., 2015; Trinh and Morais, 2017). Under these circumstances, a recent government decision to protect 7.0 million hectares of planted rice land, without justification, 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 household living standard survey (VHLSS) data for 2010 to capture the economy and household economic structure before substantial policy changes in farmland use and protection implemented in the early 2010s. We find that converting some protected rice land into other crops enhances not only economic efficiency, but also overall income-based equality, albeit slightly. 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 modernizing 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 governments 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.

Rice is also important for 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; Nguyen et al., 2020). 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 (Pingali and Xuan, 1992; Che et al., 2001; Ravallion and Van de Walle, 2008; Kompas et al., 2012).

Key to the transition to a market economy was the promulgation of land laws and their revisions.¹ 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. Rice land was separated from agricultural land or annual cropland designations in the 2001 land law revision. Since then, rice land users have to plant rice, as specified in their land use certificates. This change took place in the face of the rapid urbanization beginning in the late 1990s, in major economic hubs in delta regions in particular, which are also the main rice producing areas in Vietnam.

Quantitative indicators of rice land protection are articulated in Decree No. 63/NQ-CP, issued in 2009 and Decision 124/QĐ-TTg, issued in 2012. In particular, 3.8 million hectares of existing rice land requires protection to yield an output of 41–43 million of 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’. 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. 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/QĐ-TTg in 2013). 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 in the face of threats from climate change.

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, 2011, 2016b). 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, and 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

The answer to the question of how much rice land should be protected is contingent upon the objectives of the Vietnamese government. Since the launch of its landmark ‘Renovation’ policy in 1986, Vietnam has been transforming from a command into a socialist-oriented market-based economy. That is, the government has been deliberately balancing growth and equity goals using various instruments including land policies. Until recently when challenges have arisen from changing demographics, diets, employment, other livelihood and development

opportunities, as well as environmental pressures, Vietnam had been successful in maintaining this delicate balance. Thus, in the recent ‘agricultural restructuring plan’, the government aims to increase the economic welfare of farmers by enhancing their production efficiency and productivity. It also underscores the environmental costs of intensive rice production and raises questions on whether or not having a large national surplus of rice is desirable in the face of the international market conditions for rice, given the low profitability of Vietnam’s low quality/low price position in the world rice market. The government also rules out the laissez-faire approach and stands firm on protecting farmland even though releasing it for non-agricultural uses might generate high economic benefits. Finally, given its massive investment in building an irrigation system suitable for rice production and its gradual transition approach, the government only allows conversion of rice land into land for cultivating annual agricultural products where rice can always be planted again at no or low cost.

With this in mind, we overlay a stochastic dynamic optimization model on top of a dynamic GE framework. This framework allows us to answer the question of how much rice land should be protected in Vietnam so that real GDP, our measure of economic efficiency, is the highest. A GE framework is needed to find real GDP for a specific allocation of rice land. Meanwhile, a dynamic optimization routine is required to investigate which rice land allocation would generate the highest 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 equation (1):

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

where ρ is a discount rate; \mathbb{E} is an expectation operator; u are random noises caused by exogenous factors; t is a time index in a yearly step; $T = 10$ is the actual planning horizon in Vietnam; r is a conversion ratio which remains constant throughout the planning horizon as per Vietnam’s policy-making practice; $\text{GDP}_t(r=0)$ is the real GDP at year t when no rice land is converted at all. At each value of r , the GE component is solved to calculate the real GDP that corresponds to each realization of u and find the difference between it and $\text{GDP}_t(r=0)$. The expected difference given u is then calculated for each level of r . Our objective is to find the r that gives the highest discounted total difference over the planning horizon.

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. That is, we calculate the Gini index for each conversion ratio using GE framework outcomes of relative price changes and household income data (outside the GE framework). 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 using household data.

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

¹ Land laws after the landmarked Doi Moi (Innovation) policy were issued in 1988, 1993 (revised in 1998 and 2001), 2003 and 2013.

land and vice versa²; 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 the three industries in equation (2):

$$q_t^i = \sum_{s \in S} Q_t^{s,i} \tag{2}$$

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 in equation (3):

$$w_t^i q_t^i = R^i w_t^i q_t^i + K_t^i w_t^K + N_t^i w_t^N + L_t^i w_t^{L^i} + \sum_j Q_t^{i,j} w_t^j, \tag{3}$$

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

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 sales 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 in equation (4):

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

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 government transfers 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 tractability.³ We specify this scenario using the system of equations (5):

$$\begin{cases} K_t &= \sum_i K_t^i, \text{ for } i \in \{rice, non-rice, others\} \\ N_t &= \sum_i N_t^i, \text{ for } i \in \{rice, non-rice, others\} \\ L_t^{others} &= L_t^{others} \\ L_t^{non-rice} + L_t^{rice} r &= L_t^{non-rice} \\ L_t^{rice} (1 - r) &= L_t^{rice} \end{cases} \tag{5}$$

² Specifically, *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 versa.

³ For example, Nielsen (2003) modelled a shift of 5% rice land into other agricultural uses in Vietnam.

where the first two equations in the system refer to the full employment assumption for capital and labour; the third equation implies that all available *others* land is used in the *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 of equations (5) denotes the total available resources, and the time index t is only needed in equations for 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 foods 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 of equations (5) except the last two equations being in the form:

$$\begin{cases} L_t^{rice} + L_t^{non-rice} &= L_t^{rice} + L_t^{non-rice} \\ (1 - R^{L^{rice}})w_t^{rice} - (1 - R^{L^{non-rice}})w_t^{non-rice} &= 0 \end{cases} \tag{6}$$

where $R^{L^{rice}}$ and $R^{L^{non-rice}}$ are land taxes on *rice* and *non-rice* land. In essence, the equations in the system of equations (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 the two industries are equalized. We call this case "minimum protection". We formalize this case in the system of equation (7) by changing the last two equations in the system (5) using the Kuhn-Tucker conditions:

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

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

The final set of conditions captures the dynamics of total labor in equation (8) and capital in equation (9):

$$N_{t+1} = (1 + g)N_t \quad \text{for } t = 0, 1, \dots, T - 1 \tag{8}$$

$$K_{t+1} = K_t + \theta I_t - \delta K_t \quad \text{for } t = 0, 1, \dots, T - 1 \tag{9}$$

where g is the 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 Supplementary Materials. Finally, GDP is calculated using the expenditure approach as shown in equation (10):

$$GDP_t = \sum_i \left[(Q_t^{H,i} + Q_t^{G,i} + Q_t^{I,i} + Q_t^{ex,i}) w_t^i \right] - w_0^{im} \sum_j Q_t^{i,j} \tag{10}$$

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

It is worth noting that our model does not consider the effect of the exchange rate explicitly even though increased/reduced rice production and exports could potentially affect production in other industries through national currency appreciation/depreciation. The reasons are twofold. First, the *rice* land is released to *non-rice* land with an aim to increase production and reduce imports of livestock feed, which has been increasing recently as the diet is shifting towards meat. Therefore, the resulting net exports would not vary substantially, causing little change

to the exchange rate. Second, the government of Vietnam still manages the national currency's exchange rate against the USD to maintain monetary stability, thus mitigating negative impacts on the country's competitiveness.

To conclude this sub-section, it is important to note that our GE framework is simple⁴ 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 accommodate 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 methodology (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.

⁴ The stochastic optimization problem involves solving a large number of the GE models, each of which has a different value of r and a realization of uncertainty. To ease computation, the GE component is constructed with aggregate sectors such as rice, non-rice crops, and others. This GE component is an aggregate version of more detailed CGE models for Vietnam, such as those used by Ha et al. (2015), Giesecke and Nhi (2009), and Giesecke et al. (2013).

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

Overall inequality can be measured using household data and the income Gini index proposed by Gini (1921) in equation (11):

$$Gini_t = \frac{\sum_{h_1=1}^n \sum_{h_2=1}^n |y_t^{h_1} - y_t^{h_2}|}{2n^2 \sum_{h=1}^n y_t^h} \tag{11}$$

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 $y_t^{H_i}$, 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 $i \in \{rice, non-rice, others, capital, labour, rice-land, non-rice-land, others-land\}$

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_i^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.

To measure the change in inequality, we use the price outcomes from the GE framework, which vary by the land conversion ratio (r) and the realization of uncertain factors (u), simulated sequentially on the household survey data. Thus, the percentage change in income inequality for year t , $\Delta IEQ_t(r)$, caused by the change in *rice* land policy is measured by equation (12):

$$\Delta IEQ_t(r) = \frac{Gini_t(r) - Gini_t(0)}{Gini_t(0)} \times 100\% \tag{12}$$

where $Gini_t(r)$ is the income Gini index when a proportion r of the current *rice* land is converted into *non-rice* land and $Gini_t(0)$ is the income Gini index when no *rice* land is converted. We use the income Gini index instead of an expenditure index since it 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 world.⁵ 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 in equation (13):

$$\Delta CS_t^{h,i}(r) \cong -C^{h,i} \left[w_t^{h,i}(r) - w_t^{h,i}(0) \right] = - \underbrace{C^{h,i} w_t^{h,i}(0)}_{\text{Consumption value}} \underbrace{\frac{\Delta w_t^{h,i}}{w_t^{h,i}(0)}}_{\% \text{ change in price}} \tag{13}$$

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

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 the economic modelling. Under this assumption, $\Delta CS_t^{h,i}(r)$ is a product of its initial consumption value and the

⁵ See 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.

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 (equation (14)) which takes into account the consumer's response (or the long-term impact) even though they are typically in the same direction (Ivanic and Martin, 2008):

$$\Delta C S_t^{h,i}(r) \cong -C^{h,i} w_t^{h,i}(0) \frac{\Delta w^{h,i}}{w_t^{h,i}(0)} - 0.5 \varepsilon_d^i C^{h,i} w_t^{h,i}(0) \left[\frac{\Delta w^{h,i}}{w_t^{h,i}(0)} \right]^2 \quad (14)$$

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

Likewise, the second-order approximation of the change in producer surplus, $\Delta P S_t^{h,i}(r)$, can be calculated by equation (15):

$$\begin{aligned} \Delta P S_t^{h,i}(r) &\cong q^{h,i} \left[w_t^i(r) - w_t^i(0) \right] \\ &\cong \underbrace{q^{h,i} w_t^{h,i}(0)}_{\text{Revenues}} \underbrace{\frac{\Delta w^{h,i}}{w_t^{h,i}(0)}}_{\% \text{ change in price}} + 0.5 \varepsilon_s^i q^{h,i} w_t^{h,i}(0) \left[\frac{\Delta w^{h,i}}{w_t^{h,i}(0)} \right]^2 \end{aligned} \quad (15)$$

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

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, $N B_t^h(r)$, which is calculated by equation (16):

$$N B_t^h(r) = \sum_i \left[\Delta P S_t^{h,i}(r) + \Delta C S_t^{h,i}(r) \right] \quad (16)$$

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

and the average of household yearly net benefit ratio during the planning horizon, $\overline{N B R}_t^h(r)$, is measured using equation (17):

$$\overline{N B R}_t^h(r) = \frac{1}{T} \sum_t \frac{N B_t^h(r)}{y_0^h} \quad (17)$$

which compares the net benefit a household gains/loses each year against its initial wealth, proxied by its initial expenditure y_0^h before any policy changes.

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 values.⁶ Finally, for brevity, we only present results using the optimal conversion ratio r^{optimal} obtained from our dynamic optimization in the *minimum protection* case.

3.4. Impact on food security

Food security is defined by the Food and Agriculture Organization (FAO) as having four interrelated elements: availability, access, utilization and stability (McGuire, 2015). In the context of rice in Vietnam, where the rice market is generally regulated by the Government to harmonize the benefits of consumers and producers, we consider (at the risk of over-simplification) food security is achieved when the supply of rice meets its demand at the country level.

⁶ In particular, we multiply each net present values of the streams of surpluses and net benefits with $(1 - \kappa)/[\kappa(1 - \kappa^T)]$ where $\kappa = \frac{1}{1 + \rho}$.

4. Model parameterization and data

For the stochastic dynamic optimization model, information on the annual discount factor and the 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 rice producing 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 for 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 Vietnam constructed by CIEM-WIDER (2014), while parameters (Table 2) come from various sources. The CES coefficients for *rice* and *non-rice* production are 0.45 (Hoang, 2015) while the corresponding value for *other* industries is equal to 1 (Gabriel and Daniel, 2014). Their ranges for sensitivity analysis come from their own sources. The price elasticity coefficients for *rice* and *non-rice* exports are -4.5 (Giesecke and Nhi, 2009). Their lower bound for sensitivity analysis is -2, an estimate for Thailand by Warr and Wollmer (1997), while the upper bound is the sum of the baseline value and the difference between the baseline and the lower bound values. The CES coefficient measuring the substitutability between the necessity and non-necessity composite goods (Supplementary Materials) is found to be 0.05 by Hoang and Meyers (2015). Its range for sensitivity analysis is 60% from the baseline value. All parameter values are commensurate with those used in the MONASH-VN, a CGE model for Vietnam (Giesecke and Nhi, 2009), and the ThaiGem, an ORANI-G model for Thailand (CoPS, 2018). Furthermore, the annual depreciation of capital (equation (9)) is 10% according to Ministry of Finance's decision (MOF, 2015). Finally, annual labour force growth (equation (8)) is 1%, considering both Vietnam's average growth of 1.7% during 2010-2014 (General Statistic Office, 2016b) and its future population projection of 1% in 2017, declining to 0.6% in 2027 (FAO, 2017).

Microsimulation requires information on demand and supply elasticities (Table 3) and household data. For the former, we choose the Marshallian own-price elasticity estimates by Vu (2008) which consider both quality and measurement error problems, and are available by quintile, urban/rural and by region.⁷ Furthermore, his estimates for rice and staples are suitable for our commodity grouping of *rice* and *non-rice*. 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.

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 this group largely comprises commodities

⁷ There are other estimates by Le (2008); Benjamin and Brandt (2004); Minot and Goletti (2000). Except for Le (2008), they use data collected in 1990s which do not reflect the current Vietnamese diet.

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 land</i>	<i>non-rice land</i>	<i>others land</i>	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 land</i>	2551	0	0										2551
<i>non-rice land</i>	0	1799	0										1799
<i>others land</i>	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}	-4.5	Warr and Wollmer (1997); Giesecke and Nhi (2009); CoPS (2018)	[-2,-7]
Price elasticity coefficient of <i>non-rice</i> exports	$\epsilon^{non-rice}$	-4.5	-ditto-	[-2,-7]
Price elasticity coefficient of <i>others</i> exports	ϵ^{others}	-8	-ditto-	[-5,-11]
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%]

Table 3. Demand and Supply Elasticity Estimates.

Group	Demand Elasticity ^(a)			Supply 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 labour supply elasticities are 0.46 (Domeij and Floden, 2006); supply elasticities of different land types and capital are set to zero since households do not produce capital while having little control over land supply, at least in the short- and medium term. Demand elasticity estimates by ethnic group are not available so we use those by income group. Likewise, supply elasticity estimates by urban/rural and income group are not available so we use those by region.

^(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) We assume that household supply elasticity for *others* is zero since this group largely comprises of commodities produced by manufacturing and processing industries.

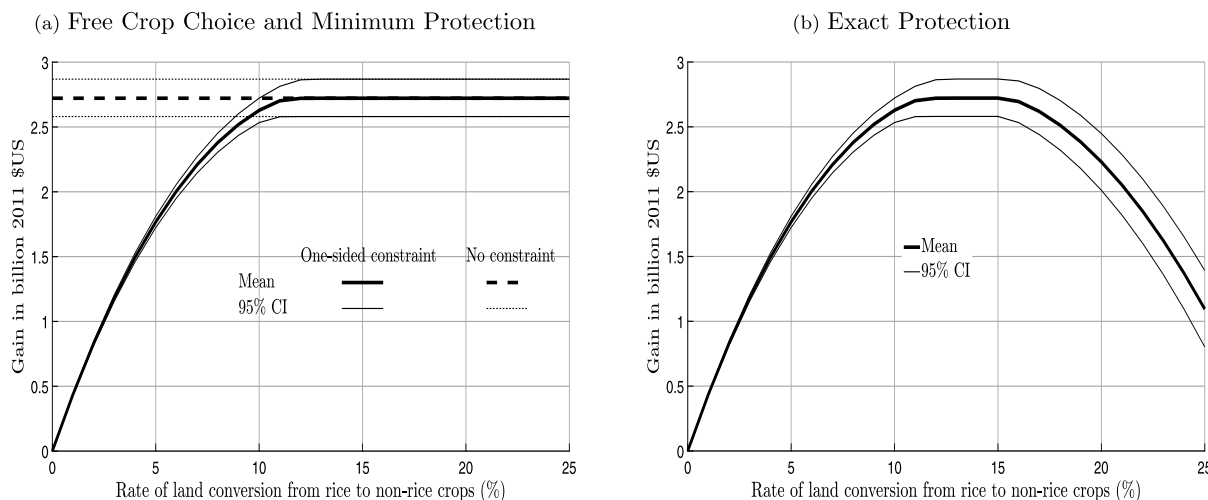


Fig. 1. Land rice conversion and real GDP change in the cases of Free Crop Choice, Minimum Protection and Exact Protection.

produced by manufacturing and processing industries. Meanwhile, the labour supply elasticity is 0.46 (Domeij and Floden, 2006) while supply elasticities for land and capital are zero since households do not produce capital while having little control over land supply, at least in the short- and medium-term.

Household data come from VHLSS 2010, a nationally representative household survey. Although there are more updated versions, 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 categories. 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 a 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

Fig. 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 USD 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.⁸ 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 \$333 USD/planted ha.⁹

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

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 the rice 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.

⁸ The study by Giesecke and Nhi (2009) also suggests that reduction in rice land in Vietnam would increase the national GDP but the study did not attempt to identify an optimal level of rice land protection.

⁹ That is, the total rental costs for rice and non-rice land are \$2,551 million USD and \$1,799 million USD 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).

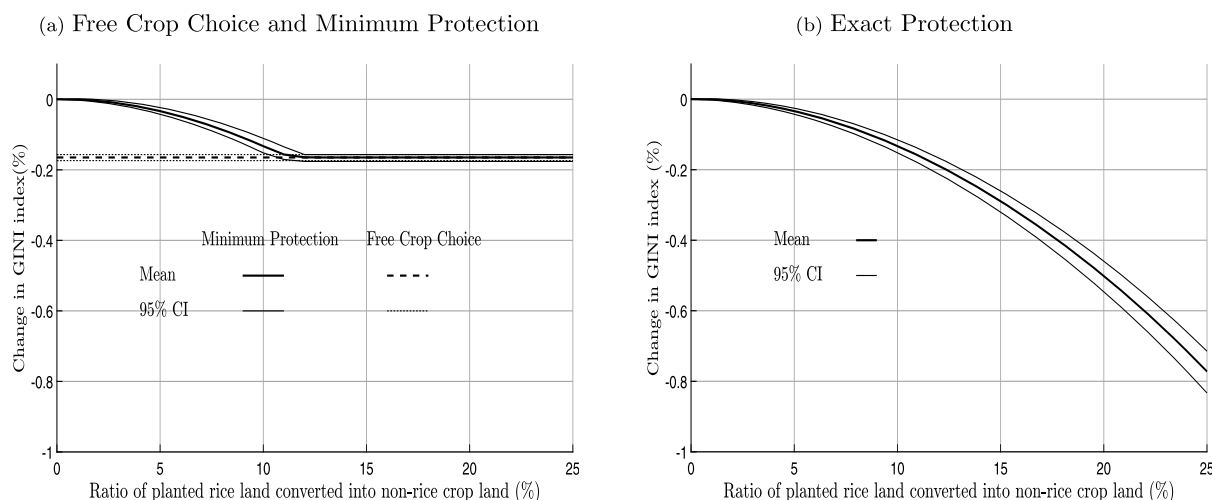


Fig. 2. Land rice conversion and change in Gini index in the cases of Free Crop Choice, Minimum Protection and Exact Protection.

5.2. Impact on inequality

Fig. 2 presents changes in overall equality in the three different constraint modelling cases. In *Free Crop Choice* (Fig. 2a), 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* (Fig. 2a), 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* (Fig. 2b). This result is counter-intuitive, and, again, solely driven by the assumption that farmers precisely follow 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 prices against non-rice prices. 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.

In summary, if farmers have more crop choice, overall equality would likely improve, though slightly.

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 in Table 4. 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, ethnic minority groups 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 and ethnic majority households are more likely to purchase rice. Across regions, households in the Central Highlands (CH) and the 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. All estimates are statistically significant at the 1% level.

Overall, the optimal rice land conversion policy results in an increase of \$2.8 USD in NB per person (column 12). Taking Vietnam’s population of about 90 million people as a whole, this gain amounts to about \$252 million USD. Nonetheless, comparing with household expenditure per person, the gain is negligible ($\overline{NBR} = 0.1\%$, column 13).

A closer look at different disaggregated household groups reveals a contrasting picture. Urban dwellers gain 4.1 USD in NB per person, about double that of their rural counterparts primarily due to their gain on the consumption side. In fact, shifting away from rice to consuming more products in non-rice such as vegetables, fast-growing fruits, nuts, sugar, starchy and tuber crops, etc., implies that urban and rich consumers are likely better off when rice price increases and prices of non-rice fall. Meanwhile, a modest gain in the producer surplus of rural households indicates that rice production no longer plays a principal role in rural household activities, as it once did. \overline{NBR} estimates suggest that an average urban household would gain but their rural fellows would lose, albeit negligibly.

The difference by ethnicity is much more worrisome, however. The ethnic minority which comprises 52 small groups, representing about 17% of the population but most of the poor, are made worse off based on every single measurement criterion (columns 10-13). However, the opposite is true for the ethnic majority which includes households whose heads are Kinh and Chinese. The loss experienced by the ethnic minority is more pronounced on the production side (column 11). The result is plausible since those households are often found to live in the Northern Mountains (MNM) and CH, which are characterised by difficult terrains and inadequate irrigation. Therefore, even though a higher proportion of them produce rice more than enough for their consumption than the majority, their production is just barely above the subsistence level. Meanwhile, they eat more rice because they are poor, and they earn more income from non-price agricultural products due to their farm soil conditions. Thus, an increase in rice price and a reduction in non-rice price is expected to lessen their welfare by 7 USD per annum or 2.4% of their expenditure level (columns 12-13).

Among the 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 all others, by contrast, consumers gain, but producers lose (columns 10-13). This result is similar to the one by Minot and Goletti (1998, table 1) who use household data more than a decade before, and thus suggests a persistent pattern in the

Table 4. 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	1.3 [0.000]	1.2 [0.2]	2.4 [0.000]	0.03 [0.000]	1.6 [0.000]	1.2 [0.2]	2.8 [0.000]	0.1 [0.000]
Urban	30.5	8.1	1.0	90.9	2.6 [0.1]	1.2 [0.5]	3.8 [0.5]	0.3 [0.000]	2.9 [0.1]	1.2 [0.5]	4.1 [0.5]	0.3 [0.000]
Rural	69.5	45.0	0.2	54.8	0.7 [0.04]	1.1 [0.3]	1.8 [0.3]	-0.1 [0.001]	1.0 [0.05]	1.2 [0.3]	2.2 [0.3]	-0.01 [0.001]
Majority	83.0	31.8	0.4	67.8	1.6 [0.000]	2.2 [0.1]	3.8 [0.000]	0.4 [0.000]	1.9 [0.000]	2.3 [0.1]	4.2 [0.000]	0.5 [0.000]
Minority	17.0	47.5	0.2	52.3	-0.9 [0.000]	-6.3 [0.1]	-7.2 [0.001]	-2.5 [0.001]	-0.6 [0.000]	-6.2 [0.1]	-6.9 [0.001]	-2.4 [0.001]
RRD	24.8	47.0	0.0	53.0	1.2 [0.000]	3.0 [0.03]	4.3 [0.000]	0.6 [0.000]	1.6 [0.000]	3.1 [0.03]	4.7 [0.000]	0.6 [0.000]
MNM	12.6	47.5	0.2	52.3	-0.7 [0.000]	-4.7 [0.05]	-5.4 [0.000]	-1.7 [0.000]	-0.4 [0.000]	-4.7 [0.05]	-5.1 [0.000]	-1.6 [0.000]
NCC	21.7	40.5	0.0	59.5	0.9 [0.000]	-2.1 [0.1]	-1.2 [0.000]	-0.4 [0.000]	1.2 [0.000]	-2.0 [0.1]	-0.8 [0.000]	-0.4 [0.000]
CH	5.4	19.5	0.3	80.2	0.4 [0.000]	-8.7 [0.1]	-8.2 [0.001]	-2.3 [0.001]	0.7 [0.000]	-8.7 [0.1]	-7.9 [0.001]	-2.2 [0.001]
SE	16.8	3.9	1.9	94.2	2.7 [0.000]	-1.4 [0.1]	1.4 [0.001]	0.03 [0.000]	3.1 [0.000]	-1.3 [0.1]	1.7 [0.001]	0.1 [0.000]
MRD	18.8	30.1	0.3	69.6	1.9 [0.000]	11.4 [0.2]	13.3 [0.000]	1.7 [0.001]	2.4 [0.000]	11.4 [0.2]	13.8 [0.000]	1.8 [0.001]
Poorest	8.0	45.8	0.2	54.0	-1.0 [0.000]	-3.0 [0.02]	-4.0 [0.000]	-2.0 [0.001]	-0.8 [0.000]	-3.0 [0.02]	-3.8 [0.000]	-1.9 [0.001]
2nd	9.2	42.8	0.2	57.0	-0.7 [0.000]	-2.0 [0.03]	-2.7 [0.000]	-0.8 [0.001]	-0.4 [0.000]	-2.0 [0.03]	-2.4 [0.000]	-0.7 [0.001]
3rd	9.1	48.7	0.1	51.2	-0.3 [0.000]	-1.2 [0.04]	-1.5 [0.000]	-0.3 [0.001]	0.01 [0.000]	-1.2 [0.04]	-1.2 [0.000]	-0.3 [0.001]
4th	9.7	48.5	0.0	51.5	0.1 [0.000]	1.4 [0.04]	1.5 [0.000]	0.3 [0.000]	0.4 [0.000]	1.4 [0.04]	1.8 [0.000]	0.4 [0.000]
5th	9.8	43.4	0.1	56.5	0.5 [0.000]	1.4 [0.1]	1.9 [0.000]	0.3 [0.000]	0.8 [0.000]	1.4 [0.1]	2.3 [0.000]	0.4 [0.000]
6th	10.0	40.3	0.6	59.1	1.0 [0.000]	2.1 [0.1]	3.1 [0.000]	0.5 [0.000]	1.3 [0.000]	2.2 [0.1]	3.5 [0.000]	0.5 [0.000]
7th	10.7	31.1	0.3	68.6	1.3 [0.000]	1.5 [0.1]	2.8 [0.000]	0.4 [0.000]	1.7 [0.000]	1.6 [0.1]	3.2 [0.000]	0.4 [0.000]
8th	10.8	27.9	0.2	71.9	2.0 [0.000]	4.3 [0.1]	6.3 [0.000]	0.6 [0.000]	2.4 [0.000]	4.3 [0.1]	6.7 [0.000]	0.7 [0.000]
9th	11.0	16.1	0.4	83.5	2.9 [0.000]	3.7 [0.1]	6.7 [0.000]	0.5 [0.000]	3.3 [0.000]	3.8 [0.1]	7.1 [0.000]	0.5 [0.000]
Richest	11.7	5.3	1.7	93.0	5.1 [0.000]	1.4 [0.1]	6.5 [0.000]	0.3 [0.000]	5.6 [0.000]	1.4 [0.1]	6.9 [0.000]	0.3 [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. All estimates are statistically significant at the 1% level.

regional distribution of rice production and consumption in Vietnam. Specifically, CH and Midlands and 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. Moreover, CH and MNM have the highest proportions of poor and ethnic minority households, whose diet is dominated by rice, so consumer gains here are also 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 from this rice land conversion policy. In column 10 on consumer surplus, the two poorest groups are made worse off. For other groups, the richer they are, the more gain they enjoy. 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 et al., 1989). Regarding producer surplus, it is evident that the poorest 30% households experience the largest losses while the gain is the highest among the upper middle-income households. Put all together, the

biggest losers are the bottom three income groups 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. Impact on food security

There is no impact on food security now or in the future when 13% of *rice* land is converted into *non-rice* area. The reason is that Vietnam only needs about 4.5 million planted ha or 60% of the optimal planted rice land, at the most, to feed its population even at the peak of 109 million people projected in 2060 (United Nations, 2019). This estimate is calculated based on conservative assumptions that Vietnamese consumption per capita and rice yield remain unchanged, being 145 kg/year and 5.47 tons of paddy/ha, respectively, and the conversion rate from paddy into rice of 0.67 (FAO, 2017).

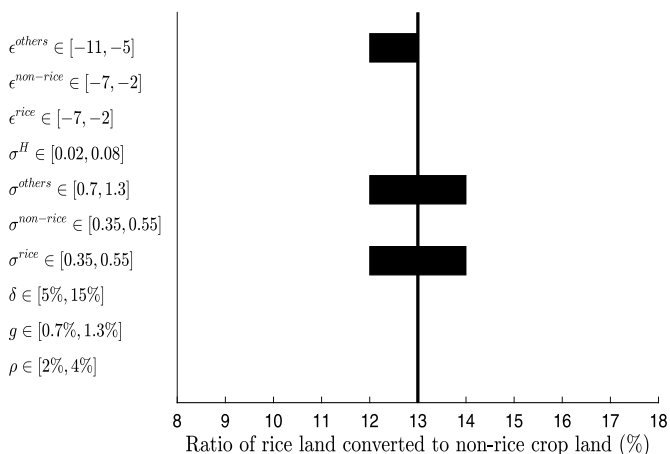


Fig. 3. Sensitivity analysis of the optimal conversion rate.

5.5. 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 $\pm 60\%$. The model outcomes are presented in Fig. 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.

6. Discussion

This paper contributes to the literature on ALP by quantifying 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 the 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, wealth distribution by region, urban/rural, wealth-rank status and ethnic group and food security.

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 USD or one percent of real GDP over the planning horizon of 10 years, with a slight overall reduction in income-based inequality by 0.15%. The policy imposes no threat at the present or in the future to food security. 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 terrain and poor infrastructure, as well as the fact that Vietnam generally lacks effective social safety networks due to its low level of development, this outcome presents a challenge for decision-makers in Vietnam. This challenge can (perhaps) be addressed by using some of the \$2.3 billion USD gain to compensate the poor by direct transfer.

6.2. Contributions, limitations and future research

Existing economic literature on ALP largely focuses on the welfare and efficiency impacts or the amount of farmland lost. While providing useful insights, this work provides little guidance in answering 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 micro-simulations to shed light on changes in inequality and distributional welfare impacts. To this end, our framework provides useful evidence to guide policy-making, and certainly so compared to the practice of simply setting agricultural land aside in an arbitrary fashion.

With this in mind, our work sets a good example for transitional economies at large. Protection of farm land is very important in transitional economies since the risk of losing fertile farm land in an irreversible manner is the highest here, given that competition for resources is fierce and prevailing institutions are relatively weak and prone to rent-seeking and corruption. Meanwhile, the economy is growing fast and the agriculture sector usually shrinks, which leads to a further contraction in farm land. Therefore, without well-justified measures in place to protect farm land, current and future food security would likely be compromised.

Although 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 in land use often requires a tool that can help evaluate economy-wide macro and microeconomic impacts of different policy parameter values with a well-defined objective function. Indeed, one could 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 priorities.

Admittedly, our model remains quite basic because of the computational challenge in optimizing over a GE framework and the practical constraints with 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 would include both quantities for zoning and the extent of tax incentives. Furthermore, the model can be extended to take into account spatial and commodity heterogeneity, as highlighted by Gibson and Kim (2015), 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. Finally, ecological effects are worth considering in future research to ensure a sustainable development outcome from farmland protection policy.

Author contribution statement

Long Chu; Hoa-Thi-Minh Nguyen: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Tom Kompas; Khoi Dang: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Trinh Bui: Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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Appendix A. Supplementary material

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