

# GPE-VN: A general equilibrium model for the study of globalization, poverty and the environment in Vietnam<sup>1</sup>

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<sup>1</sup> This paper provides basic information and discussion relevant to applied general equilibrium experiments reported in other working papers. It is subject to periodic updates. Comments, corrections and suggestions are welcome. Address for correspondence: [coxhead@wisc.edu](mailto:coxhead@wisc.edu)

## Introduction

A growing body of research considers the implications of “globalization”, or the integration of economies with global markets, for growth, economic welfare, income distribution and the environment. It is widely agreed that globalization delivers aggregate benefits in the form of faster GDP growth, but the implications of integration with the global economy for income distribution, poverty change, and the environment are more contentious. These are serious issues in developing economies and their relationship to globalization and the policies that promote it is not yet well understood. The research described in this paper has the aim of exploring and clarifying these issues for the case of Vietnam, a developing economy that has recently undergone significant integration with global markets.

Our primary empirical tool is an applied general equilibrium (AGE) model, which we use to simulate the effects of changes in policies, prices and other important variables on output, prices, employment and factor returns, trade, and household incomes. Prior empirical analyses with Vietnamese data indicate the importance of a general equilibrium approach. The effects of trade liberalization and other reforms in the *doi moi* era have affected virtually every sector and market in the economy. This is especially true for agriculture and resource sectors, and for poverty and income distribution. Minot and Goletti (2000) used data on rice-farming households distinguished by location and income and found differential effects of welfare changes due to rice market liberalization. Litchfield et al. (2003) noted that Vietnam’s recent trade liberalization has been accompanied by a huge expansion of products intensive in the use of labor and natural resources (such as coffee, rice, handicrafts, processed foods and light manufactures) and a substantial decline in poverty, which their econometric analysis revealed to be most intense among households dependent on farming and unskilled labor incomes. These conjunctions of large poverty changes among resource-dependent sections of the population and labor force underline an important point. In countries such as Vietnam, changes in poverty do not occur in isolation from changes in the demand for and exploitation of natural resources, and vice versa; the two trends are tightly linked. *Understanding the full welfare implications of any large change, whether in domestic factor endowments and policies or in global markets, requires an economy-wide approach and integrated analysis of economic and environmental implications.* This is the goal of the overall research enterprise.

This paper summarizes our methods and data, while other papers report the results of specific policy simulations. Our CGE model is based on a modification of the “standard” template (Lofgren et al. 2002), as described below. The core database is the 2003 Vietnam Social Accounting Matrix (SAM) (Jensen and Tarp 2007). These data in turn are drawn from a variety of national accounts sources, most prominently national supply-use tables and household data from the Vietnam Household Living

Standards Survey (VHLSS). Our extrapolations from this model and database to poverty, income distribution and environment draw again on the VHLSS, and also on the World Bank's Industrial Pollution Projection System (IPPS) database.

The paper continues in the next section with a brief review of current literature. After that, we provide a description of the model and its database and a brief discussion of closure choices and solution procedures. Subsequently, we describe methods for computing poverty and distributional changes at household level, and for extrapolating from simulation results to measures of industrial pollution and pressures for changes in the use of natural resources. We conclude with a brief agenda for applied policy research with the model.

### Recent AGE models of the Vietnamese economy

A large and rapidly growing literature uses AGE models to predict the effects of trade and policy shocks on growth, the structure of production and employment, income distribution, poverty and other variables of interest to analysts and policy makers. An important early contribution examined tax policy reform options in a relatively simple model (Chan et al. 1999). The subsequent decade has seen several new contributions to analysis of Vietnamese economic development making use of applied general equilibrium methodologies—which have themselves evolved rapidly during this period. Table 1 provides a summary of Vietnam AGE models.

One group of studies uses the GTAP (Global Trade Analysis Project) model (Hertel 1997), in particular to examine the effects on the Vietnamese economy of global trade shocks and trade deals. Fukase and Martin (2000, 2001) examine the effects of the US granting MFN status to Vietnam, and of Vietnam's accession to the ASEAN Free Trade Area (AFTA), using a 13-sector AGE model. Granting of MFN status is found to increase aggregate income and lead to large increases in exports of labor-intensive manufactures such as apparel, but produced only small predicted changes in agricultural and natural resource outputs. Vanzetti and Pham (2006) also use GTAP to examine Vietnamese experience in unilateral, bilateral and multilateral trade liberalization, and obtain predictions of aggregate gains.

Trade liberalization is also the focus of several other AGE studies. Chan et al. (2004) use a model based on a 17-sector SAM to examine unilateral trade liberalization measures. This model is innovative in that it explicitly recognizes impediments to labor mobility in the Vietnamese economy. The authors construct several scenarios, including complete and costless mobility, segmented agricultural and industrial labor markets, intersectoral mobility with transactions costs, and initial unemployment with fixed real wages. Their results show the expected increases in production and exports of labor-intensive manufactures. Surprisingly, however, their model and others like it do not show trade liberalization yielding any stimulus to the resource-based sectors in which Vietnam has comparative advantage. Perhaps

because of this, simulation results with restrictions on labor mobility reveal significantly lower gains to rural poor households by comparison with the full mobility case, in which such households presumably share in the gains from output and job growth in labor-intensive manufactures.

Fujii and Roland-Holst (2008) use a 38-sector SAM linked to a spatial data set of geographical variables and household income and expenditure, from VLSS and the national census, to evaluate the effects of unilateral and global trade liberalization on poverty and income distribution. Like others of its type, this model creates a recursive link between “macro” shocks and responses and their “micro” (household) impacts. Trade shocks generate output price changes, and these in turn induce sector-level changes in factor value marginal products, which lead to intersectoral movements of labor and other allocable factors along with factor price changes. The vectors of product and factor price changes, together with any endogenous changes in taxes and transfers, then form the basis for calculations of change in household incomes and expenditures. The analytical approach permits a very detailed mapping of macro changes to poverty and incomes at household and commune level. It finds that trade liberalization raises aggregate welfare and reduce poverty in spite of generally higher inequality. Structurally, both unilateral and global liberalization produce large predicted increases in the output of apparel and other labor-intensive manufactures, but only the latter scenario also predicts an unambiguously large increase in agricultural and natural resource output. The model imposes immobility of labor between rural and urban industries, which may help explain the surprisingly small agricultural and natural resource sector response.

Cling et al. (2008) also use a macro-micro simulation model to examine trade issues. Their analysis of Vietnam’s WTO accession finds that this yields job growth, especially in industry; real wage rises, especially for unskilled workers; reductions in gender inequality; and increases in regional inequalities and between rural and urban areas. As in Chan et al. (2005), this model also incorporates a more sophisticated specification of labor markets.

An insightful recent contribution by Abbott et al. (2009) surveys this literature and makes a close and critical examination of the methodological and assumptions underlying AGE simulations of trade liberalization. In particular, Abbott et al. argue for that “trade liberalization” experiments driven only by exogenous tariff reductions underestimate the welfare gains by omitting important endogenous institutional and market responses, including changes in market access, investment decisions, and other factor market responses. Their conclusion is apt:

The key puzzle for all those engaged in ongoing, policy relevant trade policy analysis... is to identify the mechanisms through which trade influences development and so determine what limits the expansion of trade and growth, in particular sectors and overall.”

The concerns of Abbott et al. are partially addressed by incorporating economic dynamics into general equilibrium models.<sup>2</sup> But an equally important concern is to capture the realities of the most important existing policies or institutions likely to influence the response to any policy or exogenous shock. We return to this point below, in our discussion of labor markets and migration.

Environment and natural resources are another neglected area in general equilibrium evaluations of growth and development in Vietnam. There are just two published applications of AGE modeling to natural resources and the environment (El Obeid et al. 2002; Dufournaud et al. 2000). Dufournaud et al. use a highly stylized SAM-based model to examine pressures for deforestation. The paper by El Obeid et al. is part of a large research project (Beghin et al. 2002) using common AGE frameworks to examine trade-environment relationships in several developing countries. The model examines 13 types of pollutants (7 air, 4 water, and 2 land) whose emissions are linked to consumption, both as intermediate goods and in final consumption. The model uses the Vietnam SAM and contains 50 production sectors, one labor category, one representative household, and one capital type. In simulations, a business-as-usual scenario determines a reference growth and pollution trajectory in the absence of environmental or other tax reforms. The authors then examine piecemeal environmental policies and unilateral trade liberalization. The latter is found to promote both growth and pollution, particularly of airborne effluents. The composition effect of trade reform—that is, the shift in the structure of production and consumption that changing relative prices induce—shows that in Vietnam this measure would induce a relative increase in the consumption and production of dirty products. Environmental taxes alone have a variable and sometimes significant negative impact on growth, depending on the type of effluent targeted. Finally, growth-environment trade-offs are minimized when free trade is combined with emissions taxes; there is a positive impact on growth and trade, and at the same time, the country specializes in cleaner goods for export.

One drawback of current environmental analyses is that unlike many other AGE models, they contain minimal information relating to income distribution or poverty. The ownership of natural resources and the derivation of incomes from their exploitation, are both distributed in highly unequal fashion in developing economies (Deininger and Squire, 1996). Therefore, the incidence of environmental damage, such as may be caused by market responses to trade shocks or trade policies, for example, is likely to be highly differentiated by income group. There is an organic link between growth, policies, environment, and income distribution/poverty.

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<sup>2</sup> Some recent Vietnam AGE models take a dynamic approach. Nhi and Giesecke (2008) examine growth and structural change in the Vietnamese economy over the period 1996-2003. Other dynamic models have been applied to trade liberalization questions (Wong 2008; Toan 2005).

## The model

The modeling platform that we use is based on a “standard” AGE template that has been widely applied in developing countries (Lofgren et al. 2002). The template provides for factor supply, production, domestic and international trade, and consumption, savings and investment by a variety of domestic agents and institutions. Lofgren et al. (2002) provide a complete description of the model structure and is available online, so to save space and avoid duplication we merely summarize its main features and highlight points at which our model departs from the template.

*Factor markets, technology, and production.* The model identifies three aggregate primary factors: land, labor, and capital. Labor is a composite of twelve different types, distinguished by gender (M/F), location (urban/rural), and skill (low/medium/high). These categories are based on data in the 2003 SAM. The model allows for all types of factor to be employed in any sector, though in practice there are no land use data recorded in the SAM for non-agricultural industries. Moreover, in the SAM the cost shares assigned to labor do not vary across large subsets of industries (see the section on data below for more discussion of these points).

Factor demands are derived in the usual way from profit-maximizing choices made by a representative firm in each industry. The model posits a nested CES factor demand structure, with composite factor demand decisions at the top level and demands for each type of labor determined at the next level (Figure 1).

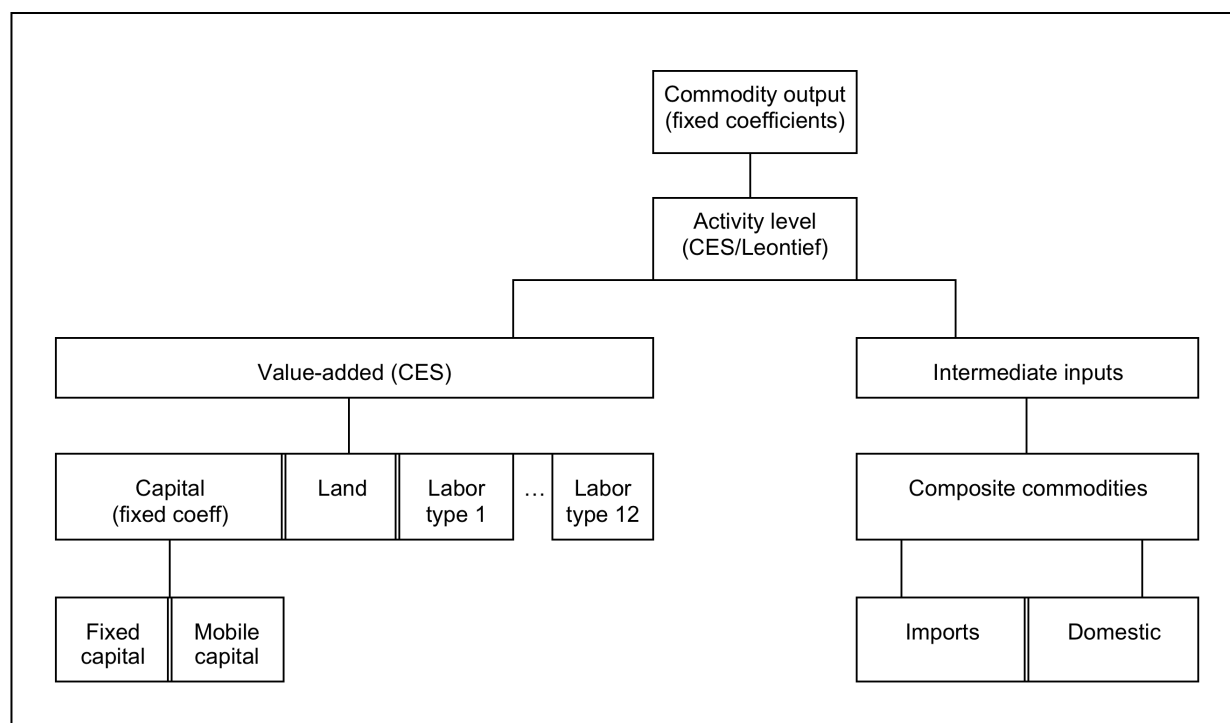


Figure 1: Production technology (Source: adapted from Lofgren et al., 2002).

Factor market closure requires assumptions on factor supply and pricing, and mobility across industries. First, we assume that some factors are available in fixed supply at the industry level. In the current version of the model, we assume that some capital is fixed in this way. In the absence of industry-level information, we assume that half the value of capital input in each sector is fixed, and the other half is mobile, meaning that it can be reallocated among sectors.<sup>3</sup> The fixed capital assumption means that changes in the return on this form of capital can vary across industries. This in turn provides indicators of the effect of a given policy shock on likely investment incentives at the industry level. Other things equal, a shock that raises returns to fixed capital in industry  $i$  relative to other industries will create incentives for higher investment in  $i$  in the next period (though the actual investment decision is not a part of this model).

Second, factors (such as labor) that are assumed to be mobile across industries can be specified either as available in elastic aggregate supply with a fixed price relative to the CPI, or available in fixed aggregate supply with an endogenous price. Either way, these factors are reallocated so as to equate the value of their marginal productivity across industries.

The treatment of land in the model is unique, and reflects the fundamental difference in Vietnamese agriculture between annual and perennial crops. Land, we assume, can be used either to grow annual crops (in the database, the paddy and “other annual crops” sectors), or for a specific perennial crop or livestock activity (see Table A-1 for a list of sectors). Land in the annual crop sectors can be reallocated among them in response to a shock: thus, the area planted to paddy may rise or fall, with a corresponding change of opposite sign in land used for “other annual crops”. Land in each perennial crop or livestock activity is instead assumed to be specific to each activity and cannot be switched to other uses.

Domestic production combines all these primary factors with intermediate goods from domestic and imported sources. Aggregate labor is combined as a CES composite with the other primary factors. The primary composite is then combined in fixed proportions with intermediates, which themselves are a CES aggregate over domestic and imported sources, to produce one output type for each sector.

*Marketing and domestic trade.* The output of each industry is a single commodity that is sold either as an intermediate good to other firms, or as a final good to households, government or the rest of the world (ROW). The movement of goods from suppliers to domestic consumers involves domestic marketing costs (margins), and exports have an additional set of margin costs. The costs of these margin

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<sup>3</sup> In Lofgren et al. (2002), all capital is assumed mobile across all industries.

services are proportionate to the costs of the services they require, which are primarily various forms of transport.

*Government and public finance.* The model assumes a single central government entity. Government earns revenues from direct taxes on households, enterprises and factors, and indirect taxes on imports, sales (value added), and ‘turnover’ (or production). There is also a small amount of government revenue received as income from the rest of the world. Government expenditure consists of transfers to households in addition to the costs of government (labor, capital and intermediate goods); Table A-2 summarizes these accounts.

*Enterprises.* The model has a single non-government corporate enterprise. It acquires earnings on capital, these are then distributed to households as profits, paid to government as taxes and transfers, used to service private foreign debt, or retained for investment.

*Households.* The model contains 16 household types, distinguished by location (urban/rural), sex of household head (M/F), and primary income source (farm, own-account, non-farm, unemployed). Table A-3 summarizes their numbers and initial incomes and poverty status. Households earn income from their ownership of labor, land and capital, and from transfers; about 70% of earned income is from labor. In the current version of the model factor endowment growth or decline is not explained; it occurs exogenously. We are developing a refinement of the specification which will allow for resource depletion and the effects of environmental externalities. Once this is implemented, household incomes may change due to endogenous environment-related changes in productive assets such as land and fixed capital. Hence there will be an element of automatic or involuntary saving or dissaving by households that control natural resources.

Households consume a subset of commodities (Table A-4 summarizes consumption patterns). They purchase goods in markets, but the model also allows for some own-account (non-marketed) consumption, primarily of agricultural goods and livestock. Household savings rates may be fixed or varied according to the closure assumption (see below). Consumption is assumed to take a Stone-Geary form, in which expenditure is allocated first to satisfaction of minimum subsistence quantities of goods, and then to ‘supernumary’ or discretionary expenditure. This yields a commodity demands in LES form (Deaton and Muellbauer 1980).

*External accounts.* We assume Vietnam to be a small country in import markets, with world prices of import goods exogenous. World demand for Vietnam’s exports does depend on export supply, however, so for some commodities (e.g. rice) a surge in exports can in principle depress the global price. The model uses an Armington structure to permit product differentiation, allowing for two-way trade in commodities and interior solutions to consumers’ choices between domestic and imported goods. In the 2003 SAM Vietnam runs a trade deficit equal to 5% of GDP. Balance of payments equilibrium is

achieved by net transfers from the rest of the world and by net remittances from Vietnamese-owned labor and capital employed abroad.

## Data

Data requirements consist of a social accounting matrix (SAM) and a set of technological and behavioral parameters governing the responsiveness of the economy to exogenous changes.

*Social accounting matrix.* The most recent SAM available from the Vietnamese Government Statistical Office (GSO) is for year 2003 and includes up to 112 sectors, 12 labor types, and 16 household types, as described above, plus government, a non-government enterprise, and the rest of the world.

Figure 2 shows the SAM in schematic form, and Figure 3 summarizes the SAM database. Basic data on households is summarized later in this paper.

Receipts	Expenditures								
	1. <i>Activities</i>	2. <i>Commodities</i>	3. <i>Factors</i>	4. <i>Private Households</i>	5. <i>Enterprises</i>	6. <i>Recurrent State</i>	7. <i>Investment/ Savings</i>	8. <i>Rest of World</i>	9. <i>Total</i>
1. <i>Activities</i>		Marketed Production		Home Consumption					Total Domestic Sales
2. <i>Commodities</i>	Intermediate Consumption	Marketing Margins		Private Marketed Consumption		State Consumption	Investment	Exports	Total Commodity Demand
3. <i>Factors</i>	Value Added								Value Added
4. <i>Private Households</i>			Wages, Salaries and Household Enterprise Profits		Distributed Profits and Social Security	Social Security and Other Current Transfers to Households		Net Foreign Transfers to Households	Private Household Income
5. <i>Enterprises</i>			Gross Profits			Enterprise subsidies		Net Foreign Transfers to Enterprises	Enterprise Income
6. <i>Recurrent State</i>	Value Added and Other Production Taxes	Commodity Taxes	Factor Taxes	Income Taxes	Enterprise Taxes			Net Foreign Transfers to State	State Revenue
7. <i>Investment/ Savings</i>				Household Savings	Retained Earnings	State Savings			Total Savings
8. <i>Rest of World</i>		Imports			Enterprise Remittances				Imports and Remittances
9. <i>Total</i>	Total Domestic Payments	Total Commodity Supply	Total Factor Payments	Allocation of Private Household Income	Total Enterprise Payments	Allocation of State Revenue	Total Investment	Total Foreign Exchange	

Figure 2: Generic Macro SAM for Vietnam (Source: Jensen et al. 2007)

Receipts (bn VND)	Expenditures (bn VND)								
	1. <i>Activities</i>	2. <i>Commodities</i>	3. <i>Factors</i>	4. <i>Private Households</i>	5. <i>Enterprises</i>	6. <i>Recurrent State</i>	7. <i>Investment/ Savings</i>	8. <i>Rest of World</i>	9. <i>Total</i>
1. <i>Activities</i>		902,462		45,713					948,175
2. <i>Commodities</i>	524,000	88,435		230,651		45,567	131,479	241,895	1,262,027
3. <i>Factors</i>	392,094								392,094
4. <i>Private Households</i>			283,017		14,523	22,758		18,886	339,184
5. <i>Enterprises</i>			97,852			3,742		2,607	104,201
6. <i>Recurrent State</i>	32,082	17,471	11,225	1,831	26,112			2,028	90,749
7. <i>Investment/ Savings</i>				60,989	51,808	18,682			131,479
8. <i>Rest of World</i>		253,659			11,758				265,416
9. <i>Total</i>	948,175	1,262,027	392,094	339,184	104,201	90,749	131,479	265,416	

Figure 3: Macro SAM for Vietnam (Source: Jensen et al. 2007).

*Elasticity data.* The complete elasticity data set includes several sets of elasticities of substitution in production, consumption and trade; elasticities of transformation in multiproduct industries; expenditure elasticities of demand; and elasticities of product and factor supply with respect to price. Estimates of the complete parameter set do not exist for any country, let alone for Vietnam. The standard approach in AGE modeling has been to assume values where estimates are unavailable, or in some cases to “borrow” them from estimates obtained in arguably similar economies.

For many components of this data set, data constraints require a similar strategy. In two critical areas, however, it is possible to obtain original econometric estimates. There is an entirely new data set containing a panel of data on land use, aquaculture area, and relevant product prices at commune level. These data will be used to estimate the responsiveness of agricultural land area and allocation to crops, and that of aquaculture area and allocation by species, to product prices. These estimates will supply parameter values for an important part of the environmental model, the responsiveness of resource users

to economic signals derived from trade or trade policy. Additional environmental data are beginning to be compiled at the Ministry of Environment and Natural Resources.

It will also be possible to obtain estimates of the responsiveness of households to product and factor market shocks from the VHLSS data. This is an essential step in moving beyond the RH model. Information on household behavior from the VHLSS can be derived only from cross-sectional estimates. With recent VHLSS rounds, however, it is becoming more feasible to use panel estimators to build in more detailed econometric information on household behavior with respect to product markets, factor (especially labor) markets, and allocation of fixed resources such as land.<sup>4</sup>

### Macroeconomic assumptions and closure rules

Equilibrium in the model is characterized by market clearing for factors and goods, endogenous trade quantities, zero profits in production, and binding household budget constraints. Choosing a closure requires assumptions about factor markets and about macroeconomic constraints. As noted above, we typically assume fixed factor quantities in the aggregate, with prices adjusting to equate demand with supply across sectors (or in the case of land and capital, subsets of sectors). This closure, however, can be substituted in the case of any or all factors with a “Keynesian” alternative in which factor supplies are elastic and their prices fixed.

We use a default macroeconomic closure in which capital transfers to and from the rest of the world are fixed and government savings and investment are fixed in real terms. In this closure, external imbalances in the trade account must be rectified by a change in the real exchange rate (the relative price of imports to domestic goods). Government tax rates and budget balance are fixed, and any excess or shortfall of government revenues over expenditures is offset by an equivalent change in the value of lump-sum transfers to households. This closure forces all endogenous adjustment onto households, thus generating EV measures of welfare change at household level.

### Solution algorithm

A model of this type can be solved in linearized form, using the GEMPACK suite of software (Harrison and Pearson, 1996). Our implementation of the model using this software relies heavily on code drawn from the ORANI-G model (Horridge, 2003). Linearization means that most results are presented in the form of percentage changes of variables from their based values. The exceptions are variables with values that may pass through zero – for example, the current account of the balance of payments and the government’s budget deficit. These enter the model as levels changes rather than as percentage changes.

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<sup>4</sup> For estimation of household food and rice consumption parameters, see Linh and Glewwe 2008.

Models of this type are sometimes criticized as being subject to linearization errors, so that larger-magnitude shocks are associated with larger (and rapidly increasing) errors in predicted outcomes. While single-step solutions of this class of model are vulnerable to this criticism, however, the software we use allows for the use of multiple-step algorithms that render such errors trivially small.

## Modifications and applications

### **Labor mobility and migration**

In developing countries like Vietnam, labor is rarely fully mobile among industries, particularly when a change in occupation also entails physical relocation. Typical barriers to mobility include constraints on departure from the origin, such as land tenure insecurity, lack of credit, cultural or other obligations.

Other constraints operate at the destination; in Vietnam, the typical costs of getting reestablished in a new location are augmented by the remnants of an internal passport system known (after its Chinese origin) as *ho khau*. The *ho khau* is a residence certificate required to gain access to social services such as schooling, health care, housing and so on. Migrants, especially from rural areas to cities, typically do not possess urban *ho khau*, and obtaining one is exceptionally difficult (Waibel, 2007).

In order to conduct experiments we must make assumptions about labor supply, pricing, and mobility across locations. Because there is little empirical research to guide us, we explore several alternative labor market closures, as follows.

*Closure 1* assumes that labor of each type is fixed in total supply, so that an increase in demand for that type of labor by some industries must be matched by an equal reduction in other industries. In this closure we also assume that rural labor cannot move to urban areas, and vice versa. Closure 1 is based on rather restrictive assumptions relative to Vietnamese reality (Phan and Coxhead 2010).

*Closure 2* retains the assumption of fixed total quantities of each type of labor, but permits interregional migration. If an urban-based industry (e.g., garments and textiles) seeks to expand, it can draw on workers of a given type (e.g., female, medium-skill) from either urban or rural regions. In equilibrium, wages for the same type of labor grow at the same rate in both regions. In this closure, migration in response to rising labor demand in specific industries provides an important channel to redistribute the gains of growth from one region to the other.

*Closure 3* alters closure 2 by assuming that the supply of some types of labor is responsive to changes in the wages offered. Job creation in one region or industry can draw in workers from others, but also stimulates an increase in total labor force participation or hours worked. Labor demand growth thus reduces unemployment and underemployment, which is quite high among unskilled workers but not,

however, for skilled workers. Accordingly we posit different labor supply elasticities by the skill and location of workers. The actual elasticity values used range from 0 to 1 (see Appendix B).

### **Environmental and natural resource accounts**

Like all industrializing economies, Vietnam faces challenges of increasing industrial pollution. The costs of pollution damage are hard to gauge accurately, but estimates from comparable economies frequently exceed 1-2% of GDP.

Deriving predictions of environmental change from a CGE model is a complex task. Some environmental and natural resource phenomena are measured as flows, others as stocks; some can be measured in monetary terms (for example, abatement measures or specific productivity losses) while values for others—particularly stocks, but also any phenomena for which markets do not exist or do not function well—can only be ascertained through valuation methods, a controversial area. The default solution is to reserve all environmental calculations to a set of “satellite accounts”, separate from the SAM. Flow data, however, can be incorporated in an extended SAM in physical (rather than monetary) terms, both for assets such as forests and minerals, and for pollutants such as industrial emissions and soil deposition in rivers, if suitable data can be found (Alarcon et al. 2000). These accounts help quantify the resource or environmental “intensity” of production and consumption activities and thus aid in assessments of the environmental implications of economic changes affecting the scale and distribution of output. In this version of the model we include most environmental data in satellite accounts.

Systematic data on industrial pollution specific to individual developing countries and industries do not exist. For lack of better sources, we match industries in the SAM with those in the World Bank’s emissions database, the Industrial Pollution Projection System (IPPS) (Hettige et al. 1994; Mani and Jha 2006). As the following notes show, this matching permits a broad-brush prediction of changes in emissions of air, water and land pollution from industry, based on changes in output.<sup>5</sup>

Assume that emissions,  $A$ , are linearly proportional to industrial output,  $Y$ .<sup>6</sup> Then for each sector  $j$  we have a pollution function  $A_j = b_j Y_j$ , where  $b_j$  is a scale factor and  $0 \leq b_j \leq 1$ . In proportional changes of variables:

$$\hat{A}_j = \hat{Y}_j,$$

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<sup>5</sup> A recent World Bank report uses IPPS coefficients to document a wide range of types of industrial pollution in Vietnam, ranking industries and provinces by the volume of estimated emissions in each category. See World Bank (2008). However, the data in this report are presented only in ordinal form, as rankings.

<sup>6</sup> Pollution can alternatively be linked to a combination of output (for scale effects) and input mix, an important refinement when considering interfuel substitution by power plants, for example, or when industries can choose among more or less polluting production processes.

where  $\hat{A}_j = dA_j / A_j$  and  $\hat{Y}_j = dY_j / Y_j$ . A change in the output of any industry alters the quantity of pollution that it emits. Aggregating over industries gives the change in total emissions due to changes in the output of all industries:

$$\hat{A} = \sum_j \hat{A}_j = \sum_j c_j \hat{Y}_j, \quad \text{where} \quad c_j = \left( \frac{b_j Y_j}{\sum_j b_j Y_j} \right).$$

The share parameter  $c_j$  can only be measured if we know the values of all  $b_j$ , which we do not. As an alternative, the value of this can be substituted, for example with value-added shares or even weights incorporating some additional form of information, such as the location of industries in relation to centers of population.<sup>7</sup> For now, we use value-added shares. This method is used to predict changes in industrial pollution in Coxhead and Nguyen (2011).

Predictions of natural resource depletion, including deforestation, are equally difficult to make from existing data and as with industrial pollution, some brave assumptions are necessary. Changes in land area devoted to different agricultural and natural resource activities can be obtained from model predictions regarding agricultural land area and/or the returns on land, depending on which is fixed. For example, if the land area is permitted to change endogenously, then in any given simulation experiment we can predict the expansion of agricultural land or fisheries area. Alternatively, if the areas are held fixed, we can use changes in returns on land to make informed guesses about pressures to expand or contract land area (or perhaps to invest in land-conserving technologies). Changes in land area—or pressures to change it, as reflected in prices—can then be used to extrapolate changes in the area covered by forest, and emissions of agricultural pollutants such as erosion from disturbed soils.

## Poverty and income distribution mappings

All poverty measures deem a household to be poor if its income or expenditure falls below a given poverty line,  $z$ . However, they differ by degree of inequality aversion, i.e. in the weight they assign to distance below  $z$ . Foster, Greer and Thorbecke (1984, hereafter FGT) present a class of poverty measures that are parametric in inequality aversion, or the degree of income inequality among the poor. These measures can be computed separately for subgroups within a population, and are additively decomposable across groups; a change in poverty in any single group alters aggregate poverty by an amount weighted by that group's population share.

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<sup>7</sup> Locational weights would be useful (again, given data availability) if we were to link emissions changes to a health damage function based on consumption of pollutants, for example.

Using  $r_h$  to denote the real (CPI-adjusted) income of household  $h$ , we can derive an expression for the change in poverty due to changes in household incomes. The central piece of data in this analysis is the household-specific *poverty gap*  $g_h = z - r_h$ . Since  $r_h$  depends on incomes from assets controlled by the household, taxes, transfers, and prices of consumption items,  $g_h$  links economic outcomes from the “macro” general equilibrium model to household-specific poverty outcomes. Using this, the proportional change in the FGT poverty measure is:

$$\hat{P}_\alpha = -\alpha \sum_{h=1}^q \mu_h(\alpha, z) \left( \frac{r_h}{z - r_h} \right) \hat{r}_h,$$

where  $\alpha > 0$  is a parameter governing the sensitivity of poverty to the distribution of income among the poor, and the weights  $\mu_h(\alpha, z) = (z - r_h)^\alpha / \sum (z - r_h)^\alpha$  are  $\alpha$ -adjusted poverty gaps for household  $h$  relative to that for all poor households (Coxhead and Warr 1995). Substituting for  $\hat{r}_h$  from the quantitative results of a policy shock applied to the model provides a prediction of household-level and aggregate poverty changes. Weighting schemes of the kind just described can also be used in theory to design optimal anti-poverty programs—or to compare existing programs with theoretically preferable counterparts.

To generate policy implications regarding poverty and income distribution, an AGE model must be capable of using the functional income distribution to compute household income. There are two approaches in doing so: the representative household (RH) approach and the micro-simulation (MS) approach. The RH approach assumes that all households in the economy can be aggregated into either one or a small number of entities, each with identical endowments and preferences. This approach is widely used because of its ease of computation, but it has a severe disadvantage. It assumes either that there is no intra-group distribution change, or that this intra-group change is linked to a theoretical statistical relationship (not an economic relationship) between the average and the variance for each group.

The MS approach improves on this by linking to larger household databases. It combines simulated outcomes for household groups within an AGE model with mappings to household survey data, including explicit modeling of behavior at household level. In the so-called top-down MS approach (Robilliard et al. 2001), the AGE model and household data simulations are run separately. The AGE

simulation produces a vector of changes in prices, wages, employment, and so on; these are then used as inputs into the micro module, where they generate unique household-level welfare results. The advantages are that the richness of household behavioral modeling is maintained and that intra-group income distributional changes are allowed. The disadvantage is that there are no feedbacks from the micro (household) data to the AGE model. Also, non-standard algorithms are needed to make the two modules numerically consistent: for example, total income in the household module must be consistent with that in the SAM. As with discrepancies observed in the national accounts, consistency is not always assured and some form of reconciliation algorithm must be adopted. The MS approach has been employed in some previous Vietnam CGE models (Fujii and Roland-Holst 2008; Cling et al. 2008); see also Coxhead, Vu and Le (2011).

In this model, we follow the MS approach. The model, as already noted, contains 16 households. Each is a composite of household data obtained from the Vietnam Household Living Standards Survey (VHLSS). Households supply productive factors, consume both marketed and non-marketed goods, save, pay taxes, and receive transfers. Their initial incomes by source, and their consumption behavior are embodied in the SAM data. Assumptions about their responses to price changes and other shocks are contained in elasticity data sets. After each simulation experiment, the outcomes for the 16 representative households are supplied to a separate module where they are mapped onto data on 4,000 households drawn from the 2004 VHLSS. The mapping is based on household characteristics (location of residence, occupation and gender of household head). Using these data, we generate continuous household-level indices of poverty and inequality. The baseline data are shown in the form of cumulative density function in Figure 4.

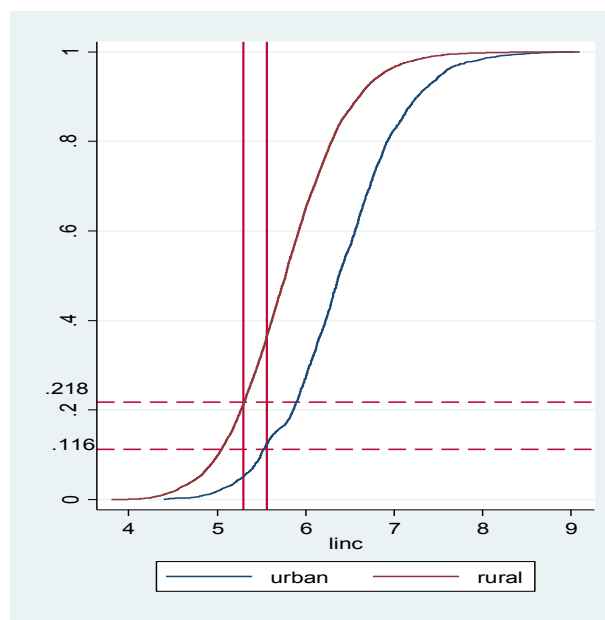


Figure 4: Cumulative density functions for rural and urban incomes. Horizontal axis: log of household income. Urban and rural poverty lines and percentage of households below them are marked on vertical axis. Source of basic data: VHLSS.

### Refinements and extensions in progress

We are presently undertaking a number of refinements and extensions to the basic model and database just described. Among other contributions, these changes will complete the task of building a model in which poverty and environmental changes are directly linked through the decisions of (among others) poor households whose livelihoods are dependent on the natural resource base. This section outlines work in progress.

### Regional decomposition of agricultural and resource industries

Many forms of pollution of environmental degradation have highly localized effects, so the value of any analysis of environmental issues is increased by access to spatial information on producers and consumers of pollution. Decomposition of economic activity by ecosystem is especially important where agriculture and natural resources are concerned. Unfortunately, the 2003 SAM database lists only 8 agricultural production sectors (paddy, rubber, coffee, tea, other crops, sugarcane, and three livestock sectors). Some of these crops are grown only in specific ecosystems: coffee, for example, is grown only in highland areas. Others are grown using different technologies in several different ecosystems. Paddy (rough rice) is the most important example, being grown in the deltas with irrigation and much more intensive practices than in either rainfed lowland areas or upland/highlands. These differences are important when

we examine agricultural supply response to price or policy shocks, technological innovations, or factor market changes. This in turn means different types of welfare outcomes for households whose incomes are derived mainly from one or other ecosystem. This is another area in which the 2003 SAM is insufficiently detailed: land is a large source of income for rural households, but to link changes in land income to household welfare it is necessary to know where the land is, and of what kind (e.g., irrigated lowland, rainfed lowland, or upland/highland). In ongoing work we aim to decompose agricultural and resource sectors by broad regions: uplands, lowlands, coastal areas and urban areas. This type of broad spatial decomposition has already been used, albeit for different regional definitions, in some data released by GSO.

### **Improving on the top-down approach to measuring poverty and inequality changes**

In the text we described the top-down approach to microsimulations of household income and expenditure. There are two other approaches extant in the literature. In the MS bottom-up approach (Cockburn 2001), data from household survey are fully integrated into the SAM, creating a SAM with thousands of households and individuals, as well as detailed information on their income, expenditures, assets, etc. This method is very demanding computationally, and thus the dimension of the SAM is usually reduced significantly, making policy simulations less informational. It might also be very difficult to integrate household data into SAM. Once integrated however, it has many advantages: (1) micro and macro modules are integrated into one, allowing feedbacks between the two modules; (2) household behavior is modeled; (3) intra-group income distributional change is allowed.

Finally, in the combined bottom-up and top-down MS approach (Savard 2003), there are also two separate micro and macro modules as in the top-down MS approach, but it allows for feedback from the micro module into the macro one. First, the CGE module generates a vector of aggregates, say wages, which is fed into the micro module to simulate household behaviors (say labor supply). These behaviors are then fed back into the CGE module to produce a new wage vector, which is then fed into the micro module again, and so on. This iteration process continues until convergence is obtained (i.e., until the differences in the results between two consecutive iterations are sufficiently close to zero). This method avoids the difficulty of integrating household survey data into SAM, and also allows the high number of activities and commodities in CGE model. The problem is that nothing guarantees a convergent solution will be found. Thus one needs to come up with non-standard tricks to accelerate convergence.

For the next step of this research, we plan to implement the top-down approach, improving on the existing method. As discussed earlier, a problem with this approach is that restrictive assumptions are usually imposed to obtain consistency. Robilliard, Bourguignon, and Robinson (2001), for instance, impose the assumption that in the equations describing household behaviors in the micro module, only the

intercept parameters change in response to a shock, not the slopes. In other words, they assume “neutrality” of the impact of a shock with respect to household and individual characteristics. This poses a serious drawback to the method, because most changes in poverty/inequality due to a shock come from the fact that different households/individuals are affected differently, and that the shock may create a new environment in which households with the different characteristics significantly change their behavior.

To improve on this method, we only need to think of a way to allow the slope parameters to also change in response to a shock. The assumption made in Robilliard, Bourguignon, and Robinson (2001) arises from a mathematical necessity: there are more parameters to be solved than constraints/equations to solve them. Thus, if we can think of a way to bring in additional constraints, this problem would be resolved. Fortunately, we have panel data of the VLSS surveys. We can utilize such panel data to explore how slope and intercept parameters change in response to changes in the economic environment. Then, such information can be combined with the standard top-down micro-simulation approach to arrive at more realistic changes in household behavior and their welfare.

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Table 1. Applied general equilibrium models of the Vietnamese economy

Article or paper	Basic model structure	SAM (year, industries)	H'hold data	Factors and factor markets	Experiments	Notes
Chan and Dung 2000		I-O 1995, 9 sectors	VLSS 92-93 (5 groups by expenditure quintile)	2 factors: labour and capital	Replace indirect tax by equal yield tax rates (gov. budget fixed)	
Chan et al 2001		I-O 1996	VLSS 97-98 (10 groups)	33 commodities, mobile cap and labor, sector-specific factors for export sectors belonging to rich HH only	Reduction of all tariff to 5%, replacing sales tax by VAT	
Chan et al. 2005		I-O 1996	VLSS97-98 (10 groups by level of expd and rural-urban)	Labor: full mobility; segmented ag and industrl markets; transactions costs; unemployment with fixed real wages	Elimination of all tariff; introduction of four-rate VAT	
Cling et al. 2008	IFPRI	CIEM 2000, 31 activities	VHLSS 2004 (9000 HH)	Capital (1), land (1), labor (12). "Wage curve" allows wage and employment changes (p.12); no rural-urban integration	WTO accession (tariff cut, foreign demand increase, FDI inflow)	
Cloutier et al. 2008	Cockburn (2007)	CIEM 2000, 5 activities	VLSS 1997/98; 4 HH types (rural-urban, ag-nonag)	Capital (1), land (1), Labor (2: skilled, unskilled). Labor mobility within skill categories	50% reduction in public subsidy on education (resulting in reduction in sales tax given gov. deficit fixed)	
Doanh, Nguyen Khanh and Yoon Heo 2009	Chan and Dung	I-O 2000, 17 activities	VHLSS 2004 (10 HH by expenditure quintile, rural/urban)	Capital (1), labor (1), foreign capital (1), sector-specific factor (17)	Tariff cut (different/equal across sectors)	

Dimaranan et al 2005	GTAP-DD	GTAP 6 database; SAM 1997 (22 sectors)			Quota abolished; tariff reductions	Distinguish domestically-oriented vs. export-oriented with implication on different duties paid
Fujii and Roland-Holst 2008		SAM 2000, 97 activities	VLSS 97-98, 5 HH types	8 labor types (gender, skill, urban), and 5 capital	Unilateral; Full; Special and Differential treatment	
Fukase and Martin 1999a	GTAP4	GTAP database 1995; VN trade data 1996			Tariff reduction: 3 AFTA; Unilateral; and APEC	
Fukase and Martin 1999b	GTAP4	GTAP database 1995; VN trade data 1996			US Tariff reduced to MFN level	
Huong, P. 2003	Huong, P. (2000)	I-O 1996 31 activities (labor/ capital intensive)	VHLSS 1992-93 6 HH by quintile of expenditure; rural/urban	Mobile labor, fixed supply for all but skilled (farm self/non-farm self/ wage earner unskill/ wage earner skilled); mobile land; sector-specific capital (40% from HH and 60% from Gov)	tariff reduction to 5% combined by (i) across-the-board increased indirect tax; (ii) external borrowing	
Jensen et al. 2004	Two static	SAM 2000	VHLSS1998; one with 16 HH; the other 6,002 HH	Short-run fixed real wage, long-run full employment	Removal of export; of tariff; both	
Giesecke and Nhi 2010	VIPAG	113 activities	VHLSS2004: 10 HH by quintile and rural/urban	Mobile land, sector-specific capital, labor by skill	VAT simplified by (i) one rate; (ii) removal of discretionary exemption	
Roland- Holst et al 2002	CNAM (Linkage?)	SAM 1999 (18 sectors)	1 hhold	Fixed real wage in SR 13 factors: mobile labor and capital, partially mobile land, and human capital (complement to capital)	3 scenarios: BaU; WTO & domestic reform; BTA; FDI	Dynamic

Tien Dung Nguyen and Ezaki 2005	Dervis et al (1982), Nguyen (2000), Ezaki & Nguyen (2001)	10 industries, 11 countries or regions	Fragmented labor mkt (formal/informal, mobile); Immobile capital	Tariff removal b/w Vietnam and: (i) ASEAN 4; (ii) China; (iii) including East Asian NIE and Japan; including North America; (iv) multilateral liberalization		
Toan, Nguyen 2005	(**)	SAM 2000, 25 sectors	8 hholds	1 sector-specific capital; 12 mobile labor	Tariff reductions to 5% (fixed government revenue)	Dynamic
Vanzetti and Pham 2007	GTAP6	GTAP database for 2001			Unilateral; harmonised; bilateral; regional; and multilateral; free trade	
Wong 2008	DCGE, Harris, Robertson (2007)	GTAP6 (collapsed to 6 traded, 4 non-trade, & Educ)		4 reproducible, 3 evolving inputs (unskilled labor, land, natural resources)	Tariff removal (I) bilateral; (ii) unil	
				All sectorally immobile except labor mobile by government policy		

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Notes: *Model structure:*

IFPRI: Lofgren et al., 2001.

SAM: CIEM 2000: Jensen et al. 2004.

Van de Mensbrugghe (2005): WB's linkage model

Huong (2000): similar to ORANI (Dixon et al (1982)).

VIPAG: Gieske & Nhi (2008) (MONASH, Dixon & Rimmer, 2002);

GTAP-DD (Ianchovichina (2003));

CNAM: Roland-Holst, Tarp, and van der Mensbrugghe (2002)

(\*\*): Devarajan, S., and D.S.Go (1998); Diao, Yeldan and Roe (1998); Dervis, de Melo, and Robinson (1982); Vargas, Schreiner et al (1999); and Hosoe (2001).

NB: Abbott et al also present a helpful survey of current models. (\*) Not a CGE study.



Table A-2: Government accounts

Income	Share (%)	Expenditure	Share (%)
Production activity tax	2.16	Goods & services	27.60
Retail sales tax	50.84	G. enterprises	11.93
Import tariffs	15.63	Transfers to households	36.94
Factor tax	9.68	Savings	20.95
Enterprise tax	11.05	ROW	2.58
Household tax	6.13		
Gov't enterprises	3.03		
ROW	1.47		

Source: Computed from 2003 VN SAM.

Table A-3: Basic household data

Household type	Number of people (000)	Population share (%)	Headcount poverty rate (%)	Share in poverty (%)
Rural	60,017	74.2	21.78	84.77
Rural male self-employed farm	32,700	40.4	26.84	56.92
Rural male self-employed non-farm	9,862	12.2	9.48	6.06
Rural male wage	3,399	4.2	14.80	3.26
Rural male unemployed	4,075	5.0	22.89	6.05
Rural female self-employed farm	4,385	5.4	22.31	6.34
Rural female self-employed non-farm	2,118	2.6	12.45	1.71
Rural female wage	462	0.6	17.67	0.53
Rural female unemployed	3,016	3.7	19.92	3.90
Urban	20,849	25.8	11.26	15.23
Urban male self-employed farm	2,476	3.1	33.02	5.30
Urban male self-employed non-farm	4,147	5.1	7.44	2.00
Urban male wage	4,172	5.2	6.50	1.76
Urban male unemployed	2,510	3.1	13.04	2.12
Urban female self-employed farm	625	0.8	24.78	1.00
Urban female self-employed non-farm	2,625	3.2	5.86	1.00
Urban female wage	1,548	1.9	4.06	0.41
Urban female unemployed	2,745	3.4	9.19	1.64
Total	80,866	100.0	19.07	100.00

Source: VHLSS.

Table A-4: Distribution of household expenditures (budget shares)

Household type	Per cent of disposable income						Savings (share of disp. Income)
	Food, beverage & tobacco	Manu- factures	Services	Marketed goods	Non- marketed goods	Tax (share of gross income)	
Rural MH Farm	0.53	0.28	0.19	0.73	0.27	0.01	0.10
Rural MH Self	0.38	0.43	0.20	0.87	0.13	0.01	0.14
Rural MH Wage	0.48	0.28	0.23	0.82	0.18	0.01	0.11
Rural MH NW	0.48	0.26	0.26	0.77	0.23	0.04	0.00
Rural FH Farm	0.51	0.28	0.22	0.76	0.24	0.01	0.09
Rural FH Self	0.45	0.28	0.27	0.87	0.13	0.01	0.15
Rural FH Wage	0.48	0.30	0.22	0.87	0.13	0.01	0.11
Rural FH NW	0.45	0.28	0.27	0.68	0.32	0.05	0.00
Urban MH Farm	0.49	0.28	0.24	0.88	0.12	0.02	0.29
Urban MH Self	0.37	0.34	0.29	0.96	0.04	0.02	0.29
Urban MH Wage	0.35	0.35	0.29	0.96	0.04	0.02	0.22
Urban MH NW	0.40	0.31	0.29	0.87	0.13	0.03	0.01
Urban FH Farm	0.47	0.33	0.21	0.87	0.13	0.03	0.18
Urban FH Self	0.38	0.33	0.29	0.96	0.04	0.02	0.24
Urban FH Wage	0.32	0.39	0.29	0.96	0.04	0.02	0.19
Urban FH NW	0.43	0.33	0.24	0.91	0.09	0.05	0.01

Source: Computed from 2003 SAM

Note: MH = Male head, FH = Female head; NW = Not working

## Appendix B: Assumed values for labor supply elasticities

In Vietnam, official sources report urban unemployment rates to be roughly steady at around 5-6%, and the ratio of rural hours worked to hours available at about 75% (reported in Brassard 2004). About 13% of rural workers are reported in official statistics as working less than full-time and seeking more hours of work in a week (Coxhead et al. 2009, Table 6). Based on our evaluation of such admittedly fragmentary data, we surmise that the supply of labor by rural workers is in general more elastic than that for urban workers; that by rural females is especially more elastic than for their urban counterparts, and the supply is more elastic for low skill labor than for medium or high-skill labor. We build a vector of labor supply elasticity values from these conjectures. The assumed values (see table A-2) range from 1 for the most elastic supplies, to 0.1 for the least. The estimation of labor supply parameters directly from household and individual data is the subject of our ongoing empirical research.

**Table B-1. Assumed values of labor supply elasticities**

Labor type	Rural	Urban
Male low skill	1.0	0.5
Male medium-skill	0.1	0.1
Male high-skill	0.1	0.1
Female low skill	1.0	0.5
Female medium-skill	1.0	0.1
Female high-skill	0.1	0.1