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What Will it Cost? Who Will Pay?**

By

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**STAFF PAPER SERIES**

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## **Vietnam's new environmental tax law: What will it cost? Who will pay?<sup>1</sup>**

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### **Abstract**

We examine the effects of a proposed environmental tax in a small open developing economy, using an applied general equilibrium model linked to a household survey database. The burden of the tax, applied primarily to fossil fuels, is passed forward by non-traded industries and backward by industries selling into the world market. It causes efficiency and competitiveness losses equivalent to those of a real exchange rate appreciation, and since export industries are in general highly labor-intensive, is regressive and thus poverty-increasing. The budget-neutral use of increased tax revenues to raise spending on anti-poverty programs can offset most of the losses of poor households, but does not create new jobs. The extent of overall losses and their distribution is sensitive to some parameters, such as labor supply response, about which little is currently known in a developing-country context.

Key words: carbon tax, environmental tax, poverty, labor market, general equilibrium, Vietnam

JEL Codes: D58, H23, O53, Q52.

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## **Vietnam's new environmental tax law: What will it cost? Who will pay?**

### **Abstract**

We evaluate a proposed environmental tax using an applied general equilibrium model linked to a household database. The burden of the tax, applied mainly to energy, is passed forward by non-tradable industries and backward by tradable industries facing fixed world prices. The tax is thus equivalent to a real exchange rate appreciation, and since export industries are labor-intensive, reduces employment and increases poverty, especially when labor supply is responsive to wages. The use of revenues to raise anti-poverty spending can offset poverty increases, but does not create jobs; thus the tax will likely conflict with other development policy objectives.

Key words: carbon tax, environmental tax, poverty, labor market, general equilibrium, Vietnam

JEL Codes: D58, H23, O53, Q52.

## **I Introduction**

In November 2010 the Government of Vietnam passed its first law on environmental taxation, to go into effect from January 2012. The law introduces new taxes on coal, gasoline and other fossil fuels, pesticides, and some other products, so it is primarily an energy tax. Such taxes have far-reaching economic effects, so as in other countries, there is considerable uncertainty over its economic implications. It is likely that reaching the nominal objectives— reduced growth rates of air pollution, water pollution and solid waste—will also require changes in the structure of production, employment, wages, and prices, and that these changes in turn will affect the distribution of household income. In trade-dependent low-income economies like Vietnam, therefore, the prospect of the energy tax raises additional concerns at the points where the tax intersects with other targets of development policy. How will the tax alter the competitiveness of industries producing exports and import substitutes? How will it alter prospects for employment growth? What effects will it have on poverty? These concerns highlight the likelihood that the new tax may compel policymakers to choose among development policy priorities.

In this paper we evaluate the likely economic impacts and incidence of the new environmental policy. The scope of the law ensures that its impacts will be felt throughout the economy. Accordingly, we adopt a general equilibrium approach, taking account of known economic linkages among production activities, employment, wages, household incomes, consumer expenditures, trade, government revenues and other important macroeconomic variables. This methodology facilitates a relatively complete assessment of the impacts and incidence of the proposed taxes. In the paper, we focus on the consequences of the proposed tax system for production, employment, and wages, and consequently for household incomes, distribution and

poverty. This in turn requires a discussion of some important parameters about which relatively little is known. Among these are elasticities of household labor supply. The environmental tax affects real wages through a number of channels, and the response of real wages in turn influences labor supply by heterogeneous actors; this determines aggregate employment effects as well as contributing to distributional and poverty outcomes. Our examination of the labor supply issue is threaded throughout the paper.

The remainder of the paper proceeds as follows. In section II we review relevant tax incidence concepts and theory. Section III introduces the model and its main datasets. The environmental tax simulation experiment is described in section IV, and the results are discussed in section V. A final section draws conclusions and identifies areas of ongoing and future research.

## **II Tax incidence in an open economy**

The economic incidence of a tax differs from the statutory (direct) incidence because the burden of the tax is passed on through product and factor markets to actors other than those on whom the statutory burden falls (Atkinson and Stiglitz 1980). The extent to which tax burden is passed forward (to consumers) or backward (to factor owners) depends on behavioral and technological responses to the tax—for example the elasticity of consumer demand for a product, or the substitutability of a less highly taxed input to production for a more highly taxed one—which are usually taken as parametric to the analysis. In general, tax burden is distributed according to relative magnitudes of relevant elasticities of demand or supply. The less elastic is demand, the more likely it is that the tax will be passed forward. In the event that demand is elastic, the tax will instead be passed backward, and in that case, the distribution of the burden among factors will depend, in part, on relative values of their supply elasticities. The values of such parameters

are thus crucial to the economic incidence of a tax.<sup>1</sup> Moreover, so long as agents are heterogeneous in terms of the assets that they supply to factor markets, the conditions under which they supply them (e.g., reservation wages), and/or the preferences they exhibit as consumers, then the shifting of the tax burden has consequences for income distribution in addition to its impacts on aggregate welfare.

These general observations come into sharp focus in small open economies, where the differences between domestic and foreign markets become important to overall tax incidence. Suppose (for simplicity) that the supply of an exportable good produced by homogeneous domestic firms is inelastic, so demand ( $D$ ) is the main determinant of its price. Denoting foreign and home markets by  $f$  and  $h$  respectively, we have  $D = D^f(p_f) + D^h(p_h)$ , with  $\partial D^i / \partial p_i < 0$ ,  $i=f,h$ . Using the total differential to find the change in total demand,

$$dD = \frac{\partial D^f}{\partial p_f} dp_f + \frac{\partial D^h}{\partial p_h} dp_h.$$

If we multiply and divide the first right-hand side term by  $D^f p_f$  and the second by  $D^h p_h$  then divide the whole by  $D$ , we have

$$\hat{D} = \frac{dD}{D} = \varepsilon_f \theta_f \hat{p}_f + \varepsilon_h (1 - \theta_f) \hat{p}_h,$$

where a “hat” denotes the proportional change in a variable;  $\varepsilon_i = (\partial D^i / \partial p_i) / (p_i / D^i)$  is the absolute value of the demand elasticity in the  $i$ ’th market, and  $\theta_f$  is the foreign share in total demand. The change in total demand is a weighted sum of price changes in each market, where the weights are price elasticities and market shares. More intuitively, if we suppose that the good in question has

close substitutes in both markets so that price changes are correlated, we can write  $\hat{p}_f = \hat{p}_h = \hat{p}$ , which (after more rearranging) yields

$$\frac{\hat{p}}{\hat{D}} = \frac{1}{(\epsilon_f - \epsilon_h)\theta_f + \epsilon_h}.$$

The change in the price of a good with respect to demand growth will be equal to  $1/\epsilon_h$  when there are no foreign sales, and  $1/(\epsilon_f - \epsilon_h)$  when there are no domestic sales. In the small country case foreign demand is elastic and therefore  $\epsilon_f \gg \epsilon_h$ . In industries whose output is sold primarily to the world market, price is unresponsive to demand shocks and the tax burden cannot be passed forward. In contrast, for industries producing lightly-traded or nontraded goods and services, demand is less elastic and prices are more responsive. These conditions apply particularly to suppliers of domestic services such as transportation, storage and trade, which are inputs to all other productive activities and have few close substitutes. If the law of one price holds, then any tax affecting costs in these intermediate services will be passed forward until it reaches the border (that is, domestic industries competing directly with foreign producers), at which point it will ‘bounce back’ onto factors of production. This is easily seen by recalling that under constant returns to scale and competitive markets, price is equal to unit cost. Given a vector of primary factors  $\mathbf{x}$  with prices  $\mathbf{w}$  and an intermediate input  $z$  with tax-inclusive price  $q(\pi) = q(1+\pi)$ , unit cost is  $p = \mathbf{w}'\mathbf{x} + q(\pi)z$ . Choose units of  $z$  such that  $q=1$ . Then in proportional change form the zero-profit condition is:

$$\hat{p} = \sum_i \phi_i \hat{w}_i + \phi_z \hat{\pi},$$



in which the  $\phi$  are cost shares and  $\sum_i \phi_i + \phi_z = 1$ . When the rate of the tax increases,  $p$  must rise and/or some  $w_i$  must fall to maintain zero pure profits. If  $p$  is constrained from increasing by limit prices set in world markets, the burden of adjustment falls instead on factors. In its turn, the distribution of this loss among factors will be strongly influenced by their relative supply elasticities. We return to this later.

If non-traded industries can pass tax burden forward while those competing at the border cannot, then in the macroeconomy, a tax on widely used inputs such as energy has effects analogous to those of a real exchange rate appreciation. It reduces the relative profitability of producing tradable goods and services, and so diminishes the country's competitiveness in world markets. This point is strikingly absent from standard carbon tax models, which omit or minimize the role of international trade (Fullerton and Heutel 2007; Metcalf 2008). The loss of tradable sector competitiveness opens (or widens) a balance of trade deficit, with a matching excess of domestic aggregate expenditure over income. For given international capital flows,<sup>2</sup> elimination of these deficits requires a combination of expenditure reduction and a fall in the relative level of domestic prices so as to depreciate the real exchange rate. Among tradable industries, higher costs and lower profits cause tax burden to be passed back in the form of lower factor prices, and ultimately to household incomes. These are likely to be important components of the adjustment to a new equilibrium. Accordingly, the shifting incidence of the tax affects not only the structure of production and trade, but also factor prices and employment, and ultimately the distribution of household income and welfare.

### ***Environmental taxes***

Environmental taxes are politically controversial, in part due to doubts over their efficacy, and in part because there is much uncertainty over their economic incidence. Economists have also struggled to identify incidence, whether in theoretical models or in quantitative analyses. Taxes on energy sources have inherently general equilibrium effects; stylized models have been used to explore structural issues (Copeland and Taylor 2003), but for applications to welfare and policy the use of applied general equilibrium (AGE) models is required.

Until very recently, AGE analyses of the incidence of environmental taxes were focused on industrialized economies. The majority of these studies find that taxes on energy are fully passed forward to consumers; as a result, they are usually found to be regressive (OECD 1994, 1995; Metcalf 2008). Possible exceptions to this regressivity are found when the tax is applied to natural resources, since the (short-run) inelasticity of their supply causes part of the tax burden to be shifted back, reducing rents that often accrue to more wealthy members of society.

For developing countries, however, the nature of any trade-off between environmental and efficiency or equity objectives remains unresolved. Most studies of carbon taxes in low-income economies use partial equilibrium methods (Ziramba et al. 2009; Datta 2010; Sterner 2011). Therefore they do not fully capture the trade competitiveness and employment linkages we have described. This is a large source of potential bias in results (Parry et al. 2005). Among general equilibrium studies, Coxhead (2000) showed that in a developing-country setting, imposing a pollution tax need not reduce real wages. The most pollution-intensive industries are typically capital-intensive; a tax that reduces their profitability has general equilibrium effects through the real exchange rate that cause labor demand in cleaner and more labor-intensive industries to expand. The key to this result is that polluting industries produce tradables, and so are

constrained by the elasticity of demand in world market from passing costs forward in higher prices. Similarly, Yusuf (2008) showed that a reduction in fuel subsidies need not be regressive in Indonesia, depending on compensation schemes implemented alongside the tax reform. In general, however, when tax burden is passed backward rather than forward, new sources of distributional concern arise, and these are linked directly to the elasticity of factor supply.<sup>3</sup>

### **III Methods and data**

#### ***The model and database***

We use an AGE model of the Vietnamese economy. Such models represent the entire economy in numerical form. They combine baseline data from national accounts and other sources about the activities of firms, households, enterprises and government with theory-based specifications about market operation, factor supplies, trade balances and other constraints, and the assumed behavior of foreign partners in trade and investment. They thus provide a consistent interface between macro and micro phenomena, at least in the realm of the real economy.<sup>4</sup>

We seek to observe the effects of tax policy shocks on prices, production and factor demand, and through these, on markets for labor, land and capital and thus on household incomes and wellbeing. Because households are heterogeneous in terms of asset ownership, income, and expenditure we can also measure effects on income distribution and poverty. The model is based on the well-known “IFPRI model” (Lofgren et al. 2002), modified to fit Vietnamese data, and is described more fully in Coxhead et al. (2010). Here, to save space we merely summarize the model’s main features.

The model identifies 112 sectors, each producing a single commodity. There are three aggregate primary factors: land, labor, and capital. Land is used only in agriculture and natural resource sectors. Capital has two components: part of the stock is mobile among sectors, while another part is specific to each sector. Labor is composed 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 Vietnam Social Accounting Matrix (SAM) (Jensen and Tarp, 2007). Labor demands are derived in the usual way from profit-maximizing choices made by a representative firm in each industry. The model posits a nested factor demand structure, with composite factor demand decisions at the top level and demands for each type of labor determined at the next level; these are governed by constant elasticity of substitution (CES) production technology. Similarly, intermediate inputs used in each industry are aggregated into a composite input using CES technology. This implies the possibility of interfuel substitution when tax increases energy prices at different rates — an important feature for any environmental tax study. The model allows for two-way trade in each good, although the data contains some pure non-traded goods such as government and community services.

Despite two decades of rapid growth, Vietnam remains a very small player in global trade. Our model reflects this by assuming fixed world prices of Vietnam's imports and highly elastic global demand for its exports. This "small open economy" representation distinguishes this model from most environmental tax models for the US and other industrialized economies, in which domestic markets typically dominate trade. In those models, all virtually all tax burden is passed forward to as higher prices to domestic consumers (Bovenberg and Goulder 1996; Fullerton and Metcalf 1997).

The model contains 16 representative household types, distinguished by location (urban/rural), sex of household head (M/F), and primary income source (farming, self-employment, wage work, unemployed). These earn income from their ownership of labor, land and capital, and may receive transfers from government or enterprises, as well as remittances from the rest of the world. They consume a wide range of goods and services, both those produced domestically and those imported from abroad. There is also some non-marketed home production and consumption, mainly of foodstuffs. 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 expenditures.

### ***Links to national household survey data***

For the purpose of welfare analysis, we augment this representative household structure by linking it recursively to the individual records of the 2004 Vietnam Household Living Standards Survey (VHLSS), which contains information on a representative sample of 9,175 households nationwide. Each household in the VHLSS dataset can be linked by its location (rural/urban), gender of household head, and primary income source to one of the 16 household types in the SAM. Then the results of an experiment in the AGE model are transmitted to individual households by mapping predicted changes in prices and supply quantities of factors, consumer prices, and transfers from private and government sources onto information about household-specific assets, consumption patterns, and unearned income.<sup>5</sup> This yields household-specific predictions of income and expenditure changes associated with the *ceteris paribus* effects of a given policy shock applied to the model.

This link, from ‘macro’ model to ‘micro’ data, makes it possible simultaneously to conduct two types of experiment. One type is *macrosimulation*, or experiments in which we examine the effects of a growth or policy shock on macroeconomic aggregates such as GDP, CPI, wages, employment, and industry activity levels. The other type is *microsimulation*, in which we trace the effects of the same shock(s) to the incomes and expenditures of individual households, or to regional and other aggregates. This enables us to draw conclusions about the effects of the shock on income distribution and poverty, both nationally and for subsets of the population such as urban and rural households.<sup>6</sup>

### ***Solution method***

The model is implemented using GEMPACK software (Harrison and Pearson, 1996) and as such relies heavily on code from the well-known ORANI-G model (Horridge 2005). The model is implemented in percentage changes of variables relative to a no-tax alternative. Thus, for example, an increase of 0.5% in the CPI means that imposing the tax raises the rate of inflation (that is, the growth rate of the CPI) by 0.5% relative to its rate in the absence of the tax.

## **IV Environmental tax policy experiment<sup>7</sup>**

The core of the Vietnamese legislation is specific taxes on the volume sold of coal, gasoline and other fossil fuels, and pesticides. These taxes are intended to replace fees currently levied at the point of sale. Using current market prices, we convert these fees and specific taxes to their *ad valorem* equivalents. Table 1 shows basic data on the main products targeted by the tax. As legislated, these taxes span a range of values. The last column of the table shows the sales tax

equivalent of the median tax rate for each product. These are the rates we apply as “shocks” in our experiments.

Table 1 about here

The environmental taxes are not strictly construed as taxes on carbon;<sup>8</sup> however, they are equivalent to a tax of about \$US0.71/t of carbon dioxide equivalent (CO<sub>2</sub>e) on coal, about \$20/t on diesel, and about \$47/t on gasoline.<sup>9</sup> The latter two figures are high by international standards, and the disparity between these and the tax on coal is likely to induce interfuel substitution (where that is feasible) toward a considerably more carbon-intensive energy source.

### ***Labor supply***

In Vietnam, the labor market is the most important market in the economy from the point of view of household income, income distribution and poverty. The country’s rapid growth over the past 20 years has seen enormous reallocations of labor across industries and locations, and (increasingly, from a low base) across skill types. The numbers of workers changing both occupation and location suggest a very elastic labor market response to changing opportunities, with internal migration by workers estimated at between 0.5m and 1m per year (Phan and Coxhead 2010). In particular, there has been a surge of predominantly semi-skilled workers (i.e. those with a completed high school education) into urban labor markets. Young women in particular appear to be disproportionately represented among internal migrants, perhaps reflecting a lower opportunity cost of their labor in the source households and communities. Yet beyond these observations, surprisingly little is known quantitatively about labor supply.

We adapt the model to incorporate a simple labor supply structure. The representative household types (N=16) in the Vietnam SAM are the basic units of observation. These supply labor that is differentiated by gender, location and skills. Each of these characteristics is likely to be associated with a different supply elasticity, and the mix of labor endowments within each household type further differentiates them from one another. For a worker of gender  $i$  in region  $j$  with skills  $k$ , the labor supply function is posited as:

$$L_{ijk}^S = L_{ijk}^T * (w_{ijk} / CPI_j)^{\beta_{ijk}},$$

where superscripts  $S$  and  $T$  denote labor supplied to the market and total labor endowment respectively; the CPI is specific to location (either rural or urban), and  $\beta_{ijk} > 0$  is the elasticity of labor supply with respect to the real wage. This stylization ignores income effects and demographic sources of heterogeneity.<sup>10</sup>

Other than the initial distribution of labor endowments across households, the critical labor supply parameters are the elasticities,  $\beta$ . We have very little information on these. Classical theory often posits a horizontal labor supply curve ( $\beta=\infty$ ), but this is rarely supported by the data. Standard trade models typically assume full employment and perfectly *inelastic* labor supply ( $\beta=0$ ), but this too is unrealistic for developing countries, especially in rural areas where households typically exhibit both underemployment and unemployment. Individual workers may supply additional labor either at the intensive margin (hours worked) or the extensive margin (jobs taken by those previously unemployed). The total elasticity of labor supply is the sum of these, but most estimates for developing countries appear to apply only to the intensive margin.<sup>11</sup> Household-level labor supply is also more elastic than for individuals. If the household consists only of one or two adult members, they are likely to supply additional labor



only at the intensive margin. Rural households, however, are commonly larger and may have some adult members (in Vietnam, often young women) who are openly unemployed. These households are likely to exhibit more elastic supply at both the intensive and extensive margins.

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% (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. 2010, Table 6). From our evaluation of these admittedly fragmentary data, we surmise that labor supply 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 unskilled labor than for medium or high-skilled labor. In the model, we build a vector of  $\beta$  values from these conjectures. The assumed values (see table 2) range from 1 for the most elastic supplies, to 0.1 for the least. The estimation of labor supply parameters from household and individual data is the subject of ongoing research.

Table 2 about here

### ***Macroeconomic closure assumptions***

In order to conduct experiments we must make assumptions about the way in which the economy adjusts to any shock, choosing which variables and policy settings are exogenously fixed, and which may endogenously adjust.

We assume investment-driven savings and a fixed current account balance with no endogeneous transfers to or from the rest of the world. The latter assumption requires that the balance of trade must remain constant. This eliminates unaccounted intertemporal borrowing, forcing all

adjustment into the single period of the simulation. The fixed nominal exchange rate of VND for USD is the model's numéraire price. Therefore, when a shock applied to the model creates pressures for an imbalance on the trade account, domestic spending and (where applicable) factor employment must adjust to restore external balance.

In each closure we assume that half the capital in each industry is fixed (immobile), while the other half is mobile (it can be reallocated across industries or sectors).<sup>12</sup> We also assume that labor of a given gender and skill level is mobile across locations— that is, we assume costless rural-urban migration within the equilibrium timeframe of the model.

Vietnam's environmental tax law specifies that new revenues are to be spent on environmental programs, but provides no details on how this is to be carried out. In fact, we find no clear evidence that this issue has received serious policy attention to date. Therefore, and in order to maintain focus on the incidence of the taxes themselves, we abstract from environment-specific expenditures. We initially assume that additional revenues from the tax increases are spent in an equiproportional, across-the-board increase in government consumption of goods and services; we describe this as the “base” case (“A”).<sup>13</sup> For comparison of welfare outcomes, we assume alternatively that net changes in government revenue are redistributed as an across-the board increase in transfers to households, again leaving the government's net budget deficit unchanged. In this case, all existing transfer recipients will receive an equal percentage increase in payments (this is case “B”). However, since transfers contribute differing shares of initial income, the impact will vary across households. In general, poorer households receive a greater share of their income in transfers, so we expect them to gain disproportionately from this mechanism.

## V Simulation results

We are interested in both the structural and the distributional aspects of the incidence of the new environmental taxes. The tax experiment consists of imposing new taxes at the rates shown in column 6 of Table 1, and we run three variants. In the base case (A), as just described, we assume that transfers from government to households increase only at the same rate as other components of public spending. Also, in this closure, labor supplies are elastic as shown in the first column of Table 2. We compare this with case B, in which government uses tax revenues to increase transfer payments to poor households. For comparison with the base case, we also adopt a closure (Case C) in which the supply of all labor types is assumed fixed. Relative to Case A, this highlights the differential macroeconomic and tax incidence consequences of alternate labor supply assumptions. To save space, the tables report only the most relevant results in each case; full simulation results are available from the authors.

**Macroeconomic impacts.** Table 3 shows the main macroeconomic results for all three cases.<sup>14</sup>

In the base case (A), the model predicts that environmental taxes reduce GDP growth by -0.34% and increase the CPI growth rate by 0.44%. The taxes raise government revenues by about 4.8% (VND 6.36bn, equivalent to about \$US419m). Real absorption falls by 0.29% (about \$US200m). At the level of aggregate sectors, the tax raises costs and reduces output by 0.47% in manufacturing, 0.32% in services (which include energy-intensive transport services), and 0.21% in agriculture and resources. Aggregate sectoral employment falls by somewhat more (0.8% in manufacturing, 0.6% in services, 0.4% in agriculture). Because the supply of labor is somewhat elastic, prices of capital and land, which by contrast are assumed fixed in supply, fall further than wages in general and this induces substitution away from labor in production.

Table 3 about here

Comparing cases A and C shows the macro implications of elastic labor supply. With fixed factor supplies (case C) the aggregate production possibilities frontier remains unaltered and overall GDP falls only very slightly, whereas elastic factor supplies permit a larger response. In cases A and C, additional tax revenues are used by government to increase its consumption; given base values, this favors the aggregate services sectors relative to agriculture and manufacturing. In case B, by contrast, it is households whose spending pattern is influential at the margin, a difference that is reflected in a smaller decline in agriculture (i.e. food) output.

Among *individual industries*, the range of impacts is wide, and industry-level variation in production and prices illustrates the means by which the incidence of the taxes is shifted.

Differences among all cases are small in this respect, so we show only case A, in Table 4. The industries directly targeted by the tax are of course seriously affected. Domestic output of coal falls by -1.7%, and that of gasoline by -8.5%. Gasoline imports, which account for 56% of domestic supply, fall by -3%. Electricity and gas output rises due to interfuel substitution, and this industry's price rises along with those upon which the statutory burden of the tax falls directly. Other industries using energy as inputs to production experience cost increases.

Among these, transport industries are the most severely affected, since gasoline and other fuels account for between 22-35% of their costs. Their prices rise by between 2% (road transport) and nearly 5% (water transport). Higher transport costs mean more costly production and distribution (domestic and export margins), and so raise costs throughout the economy.

Table 4 about here

Among industries that are especially badly hurt are producers of some key natural resource and agricultural exports. An important case is that of fisheries, in which fuel accounts for 25% of input costs. When the taxes are imposed, the fisheries industry experiences a large cost increase; production falls by -3.2% and its price rises by over 6%. This sector sells its output almost exclusively in domestic markets; 67% of its sales are to seafood processors, for whom it makes up 39.5% of total cost. Consequently, even though fuel is only 9% of total cost in seafood processing, this industry suffers a major *indirect* cost increase through its purchases from fisheries. As a result, its output falls by -2.6% and exports by -2.5%. Similarly, output and exports of processed rubber, ceramics, and processed fruit and vegetables all fall. Many import-competing manufacturers are also hurt; for example, transport equipment production falls by nearly 2% and imports rise. However, the border prices of all these tradable sectors' outputs hardly change.

An important insight these results is that some industries experience much greater adjustment pressure than others. In general, energy generation and energy-intensive industries are most heavily affected, of course. But these include some industries which, because they supply domestic markets virtually free from international competition, have discretion to raise prices, thereby passing part of their input cost increase forward to other industries and final consumers. Transport services and fisheries exemplify this. Other industries produce goods for which output price is essentially set in the world market; processed seafood, rubber, and fruit and vegetable products are examples. Faced with higher costs and elastic foreign demand, these industries cannot raise prices and so must instead cut production – and jobs. Among these are several industries which are large employers, especially of unskilled labor, so their quantity-based adjustment then has relatively large impacts on wages and employment. These industries pass the tax burden back to factor owners. They are not necessarily energy-intensive in production,

but are affected by energy prices in other ways—most especially through their use of domestic transport services to source inputs and to move outputs to markets and ports.

We see the consequence of this adjustment in the wage and employment data. *Wages and other factor prices* are reduced by the taxes (Table 5). Due to migration, urban and rural wage changes are the same for each labor type. When labor supply is inelastic (case C), wage changes are fairly uniform across labor types at around -0.8%. But when labor supply elasticities differ from zero and from each other, patterns of changes in wages and aggregate employment vary. More elastic supply means smaller wage declines but larger falls in employment, and vice versa. Adding wage and employment changes, the earnings of unskilled labor fall in case A by a total of 1.3%; medium skilled by 1.6% (men) and 1.4% (women), and high-skilled by 1.9%. In case B the income declines are somewhat larger, though the same rankings across skills are preserved.

Table 5 about here

Other factor returns also decline in both nominal and real terms. Although our model does not track investment decisions, lower unit prices for fixed and mobile capital and land send a negative signal to investors that expected investment returns in the medium run will be lower (or more accurately, will rise by less) than expected.

As seen, the taxes increase prices overall due to the pervasive effects of energy cost hikes.

Higher prices for consumer goods reduce households' purchasing power, and also, in the case of elastic labor supply, reduce aggregate employment by lowering real wages, thereby triggering movement down the labor supply curve. Table 6 summarizes key *results of the tax on the real consumption expenditures of household groups*. The pre-transfer impact of the environmental taxes is to reduce real incomes for almost all household types (households not in the labor force

earn only remittances and transfers and are not directly affected by factor market changes, but these are small groups within the total population). The biggest losses are by urban household groups, whose factor incomes depend relatively heavily on high-skill labor and mobile capital.

Table 6 about here

When transfers take place in case B, the picture is very different. For some groups, including the largest (rural farm households) higher transfers are sufficient to more than make up for their factor income losses, and their real consumption rises -- albeit by a small amount. For others, however, the transfers are too small. Wage earners and non-farm self-employed workers are among the biggest losers overall, especially in urban households for whom transfers make almost no difference to total income.

We also impute *the overall effects of the environmental taxes on poverty* and aggregate inequality, by mapping changes from the simulation model to the VHLSS database. As is well known, there is more than one measure of poverty. The simplest—and least accurate—is the *headcount* measure, which merely counts the number of households with incomes below the national poverty line. A more useful measure for policy purposes is the *poverty gap*, which computes the monetary value of the distance by which each poor household falls below the poverty line. The poverty gap measure thus shows what it would cost to raise the incomes of all poor households just to the poverty line.

Table 7 shows percentage changes in each of these poverty measures and in the Gini ratio within and between groups. It is important to notice that although these predictions are aggregated into the same set of household groups as in Table 6, they are obtained from a different data set and are not precisely comparable. In calculating poverty changes from VHLSS, we apply the

predicted changes in factor prices and supply, transfers, and consumer prices to each poor household according to its endowments, initial transfer income and expenditure pattern. This gives household-specific poverty change results, which we then aggregate back up to match the 16 household types in the AGE model. Household heterogeneity within each aggregate group, and the weighting schemes used to construct the aggregations, are both sources of information (or in the latter case, potential bias) not present in the 16 representative household categories.<sup>15</sup> In addition, the real consumption changes in Table 6 represent the average for *all* households in the group, whereas the poverty changes apply only to *poor* households.

Table 7 about here

The poverty change predictions show that without transfers, the tax sharply raises poverty. The national headcount rate rises by 1.5%, and the poverty gap by 1.3%. The Gini rises, as do nearly all groupwise ratios. Almost all rural households experience rising poverty, while most urban households experience poverty declines. This is suggested by the groupwise data, but can be seen more clearly in Figure 1. This shows changes in household-level real income, grouped into centiles and ordered from lowest change to highest. Without transfers, 90% of poor rural households but only 50% of poor urban households experience some income decline.

Inclusive of transfers, the groupwise results shown in Table 7 are reversed. The environmental tax on its own is regressive, but since the pattern of government transfers is strongly progressive, these can more than offset the tax effect. From figure 2 we see that after transfers are added into household incomes, only 12% of the rural poor, and almost no urban poor, are made worse off.

Figures 3 and 4 confirm that the tax and transfer scheme is progressive across the entire income distribution. These show ranked real income changes by centiles of the total household



population. Without transfers, about 60% of both urban and rural populations are made worse off by the tax. Inclusive of the transfer, 30% of urban households are still worse off, but slightly over 80% of rural households experience some decline. Comparing this with the results for poor households only (Figures 1-2) affirms the progressive nature of the transfer.

Finally, the use of additional data from outside the model gives us an opportunity to make a tentative comment on *the environmental impacts of the proposed taxes*. For this, we apply data from the World Bank's Industrial Pollution Projection System (IPPS), which provides industry-specific estimates of air, water, and solid waste emissions per unit of output produced (Hettige et al, 1994). Details of the application of the IPPS to Vietnamese data can be found in Coxhead et al. 2010. In brief, we use IPPS estimates of emissions intensity (pollution relative to the value of production) for each industry, and multiply these by output change predictions from the tax policy simulation. After weighting by each industry's contribution to total pollution of each type, we can compute estimates of the percentage change in total emissions of each type associated with the imposition of environmental taxes. These are shown in Table 8 for case A (the other two cases are not sufficiently different to warrant separate discussion). Air and water pollution diminish by about half of one percent, and solid waste emissions by about 0.4%. It is important to note, however, that as with the other data reported from these simulation experiments, these numbers represent the extent of reduction in the *growth rate* of emissions—not reductions in the absolute emissions *levels*. Moreover, the IPPS data provide estimates only of industrial emissions, so our predictions here take no account of consumer pollution, including, importantly, private vehicle emissions and household waste streams.

Table 8 about here

## VI Discussion and conclusions

In this paper we have calculated the predicted economic impacts of a set of environmental taxes soon to be implemented in Vietnam. Our predictions are based on simulation experiments with an applied general equilibrium model of the Vietnamese economy, using the latest available complete data sets. Our approach has been to simulate the proposed environmental taxes as *ad valorem* sales taxes on three key commodities: coal, gasoline and other fuels, and pesticides. This approach is consistent with the legislation as we understand it.

Results from the model show percentage changes in variables such as prices, employment, incomes, poverty and industrial emissions *relative to trends* that they would have followed in the absence of the taxes. In order to evaluate the incidence of the taxes on household welfare, we have also posited that additional revenues associated with the new taxes be either spent on increased government consumption, or returned to households in the form of increases in the existing pattern of government transfers.

Predictions from this experiment indicate a modest but distinct decline in GDP growth. Because these are taxes on energy, their effects are pervasive. Transport sectors are especially affected, but as largely non-traded industries they pass the tax burden forward to others. As a result, energy-dependent, export-oriented industries like seafood processing experience cost increases; since their output prices are bounded by the world market, they also suffer declines in production, exports and employment. These losses are then passed back to factor owners.<sup>16</sup>

Among factors, labor is the most important channel for translating factor market outcomes into changes in household welfare. We investigate this channel under the assumption that the supply of certain types of labor is responsive to real wage changes, and also (for comparison) under the

‘standard’ assumption of full employment and zero elasticity of labor supply response. The resulting differences in predicted changes in wages and aggregate employment translate into contrasting household welfare changes. More important still is the decision by government to return additional tax revenues to households in the form of increased transfer payments. The latter are highly progressive, leading to an outcome in which the environmental taxes reduce real GDP and aggregate employment, and yet leave the poor somewhat better off than in the no-tax (or tax-and-no-transfer) case.

The experiments thus yield mixed results for policy. Vietnam’s unilateral adoption of environmental taxes, will hurt the economy’s competitiveness in global markets for a wide range of products—among them some of its large and most labor-intensive export industries. This will impede job growth, which is an important consideration in an economy where about 1m new job-seekers enter the labor force each year. On the other hand, higher revenues will enable government, in principle, to compensate poor households for losses shifted forward to them (as consumers) and backward to them (as factor owners). However, increasing the rate of lump-sum transfers to households will not contribute in a significant way to employment growth.

These experimental results should be regarded as preliminary in the absence of direct, *ex post* measures of tax incidence, but it is our view that they are sufficiently important to merit careful consideration at policy level. An initial reaction might be to regard the impending environmental taxes as a costly threat to continued economic growth and development in a lower-income economy. *We do not support this conclusion*, because other consequences of the taxes, not captured or valued in this model, have yet to be taken into account. To frame ongoing debate, we offer the following thoughts.

First, although we can estimate likely reductions in the growth of industrial emissions, we lack the information necessary to assign *valuations of the environmental benefits* of the new taxes. These may take the form of reduced abatement costs (that is, costs associated with remediation of pollution, clean-up of water supplies, waste disposal, and so on), and also reduced costs of health and other human welfare. Studies in other developing countries indicate that particulate matter and gaseous emissions from industries and vehicles have large and costly impacts on human health, as well as reducing the productivity of labor. If the environmental taxes reduce emissions growth, they will also deliver benefits in the form of a more healthy and productive workforce. These benefits should be taken into account when evaluating the net gains and losses from an environmental tax proposal. Because we do not, our results understate the gains from the proposed system of environmental taxes.

Second, in the absence of better information, we have assumed that revenue gains from the taxes are either spent on additional government consumption or transfers. These are useful mechanisms for the purpose of evaluating the incidence of the taxes themselves. But it is not by any means the only or the best way to dispose of the additional revenues. The double dividend literature identifies improvements in the efficiency of the tax system as a second gain beyond the environmental benefits themselves (Bovenberg and Goulder 1996). Distortionary taxes reduce social welfare; therefore, if revenue gains from environmental taxes (which themselves reduce distortions, by helping to correct pollution externalities) are used in budget-neutral fashion to reduce the rate of more distortionary taxes such as import tariffs or factor income taxes, then social welfare may improve. Once again, because we have not included such possibilities, our experiments may underestimate the potential social gains from an environmental tax.<sup>17</sup>

Third, environmental tax revenues could also be used, to offset cost increases in energy-intensive and/or employment-intensive industries. Our experiments show that tradable sectors in particular suffer contractions and job losses because they are unable to pass on tax-related cost increases. To minimize the impact on these industries, and therefore on national employment and export competitiveness, the Vietnamese government could consider using environmental tax receipts to compensate them, for example by means of a corporate tax rebate proportionate to their input cost increases. This revenue-recycling strategy is more narrowly targeted than that discussed in the previous paragraph, and as such bears some risks (for rent-seeking and corrupt practices) along with its potential gains. On the other hand, its potential for beneficial impacts on employment growth and export revenues may well justify such risks.

Finally, since the lower emissions create a global externality (lower GHG emissions), there is a compelling case for compensation from the international community. In principle, this could be sufficient to fully compensate for the loss of aggregate income. The UN Clean Development Mechanism (CDM), established under the Kyoto Protocol, would seem to provide a vehicle for such compensation. The CDM allows Kyoto Protocol Annex I states (mainly OECD members) to sponsor emissions-reducing projects in non-Annex I states (mainly developing countries) as a way of helping meet their own GHG reduction commitments. More than 4,000 projects have been funded to date, and by raising about \$18bn in direct carbon revenues over its 2001-12 implementation period, the CDM is the dominant emissions reduction mechanism for developing countries (World Bank 2010:262). Two issues remain, however. First, by themselves any transfers to Vietnam from the international community would no more address non-environmental development targets (such as job creation) than would compensation paid to households by the Vietnamese government – as discussed above. Second, to date all projects

funded under the CDM have been linked to specific activities such as reforestation, introduction of new technologies, fuel substitution, etc. There is (as yet) no project that rewards a country for implementing emissions-reducing incentive mechanisms such as energy taxes. Indeed, the CDM Methodology Booklet (UNFCCC 2010), which lists and describes hundreds of CDM-permissible methodologies for emissions reduction, contains no mention at all of taxes or other mechanisms based only on incentives to alter behavior. So deployment of the CDM in support of an environmental tax such as that legislated in Vietnam would seem also to require a substantial change in the mode of operation of that international mechanism.

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**Table 1. Environmental tax rate (% of base price)**

	Value of domestic (VND bn)	Sales tax revenue (VND bn)	Effective sales tax rate (%)	Domestic base price (VND)	Proposed environmental tax (per liter or ton)	Environmental tax as % of base price (median rate)
	(1)	(2)	(3)	(4)	(5)	(6)
Coal	6,762.06	553.90	8.19	450,000	30,000	6.67
Pesticides	3,701.44	208.70	5.64	190,000	5,000	2.63
Fuel*	29,971.73	2,040.37	6.81	15,000	2,000	13.33

\* Gasoline. Taxes are applied to airline fuel, diesel, kerosene, and fuel oil at somewhat lower rates.

Sources: Columns (1), (2): SAM, 2003. Column (3) = (1)/(2).

Column (4): VNeconomy.vn : <http://tinyurl.com/33cd84f>; Vatgia.com: <http://tinyurl.com/2v3g8o6>; petrolimex.com: <http://tinyurl.com/2upehoa>

Column (5): From draft Environmental Law

Column (6) = (5)/(4). This tax rate is computed net of previous per-liter (or per ton) fees and calculated at the median of legislated tax rate ranges.

**Table 2. Assumed values of labor supply elasticities**

Labor type	Elastic supply	Inelastic supply
Rural		
Male unskilled	1.0	0
Male medium-skilled	0.1	0
Male high-skilled	0.1	0
Female unskilled	1.0	0
Female medium-skilled	1.0	0
Female high-skilled	0.1	0
Urban		
Male unskilled	0.5	0
Male medium-skilled	0.1	0
Male high-skilled	0.1	0
Female unskilled	0.5	0
Female medium-skilled	0.1	0
Female high-skilled	0.1	0

**Table 3. Environmental taxes: macroeconomic impacts**

Variables	A: Elastic labor	B: Elastic labor	C: Fixed labor
	supply, no transfers	supply, transfers	supply, no transfers
Real GDP, % change	-0.34	-0.35	-0.08
Real absorption, % change	-0.29	-0.30	-0.06
CPI, % change	0.44	0.46	0.40
Government tax revenues, % change	5.04	5.11	5.26
Government revenues, change (VND bn)			
Output by aggregate sector, % change			
Agriculture	-0.21	-0.11	-0.02
Manufacturing	-0.47	-0.41	-0.31
Services	-0.32	-0.56	0.13
Employment by aggregate sector, % change			
Agriculture	-0.36	-0.22	0.05
Manufacturing	-0.81	-0.72	-0.49
Services	-0.59	-0.83	-0.01

**Table 4. Environmental tax: Impact on sector output and prices (base case, percentage changes)**

Selected sectors	Output	Price	Trade
Energy sectors		Price to intermediate purchasers	
Coal	-1.69	2.93	
Gasoline	-8.54	7.23	
Electricity/Gas	0.73	5.36	
Margins and nontraded sectors			
Road transport	-3.16	7.91	
Rail transport	-2.09	4.81	
Water transport	-4.75	8.91	
Air transport	-3.47	3.45	
Fisheries	-3.22	6.14	
Selected export sectors		fob export price*	Exports
Processed fruit & veg	-1.71	0.23	-2.22
Processed seafood	-2.73	0.26	-2.59
Processed rubber	-1.67	0.34	-3.29
Ceramics	-1.93	0.23	-2.31
Processed wood	-0.88	0.11	-1.08
Selected import-competing		cif import price	Imports
Transport eqpt	-1.91	0	1.59
Paper and pulp	-1.39	0	-0.04
Electrical machinery	-1.02	0	-0.05

\* Inclusive of export margins.

**Table 5. Environmental tax: Impact on factor employment and returns (per cent change)**

Variables	A: Elastic labor supply, no transfers		B: Elastic labor supply, transfers		C: Fixed labor supply, no transfers	
	Wage	Employment	Wage	Employment	Wage	Employment
Labor						
Male unskilled	-0.26	-1.05	-0.31	-1.15	-0.82	0
Male medium-skilled	-0.83	-0.76	-0.94	-0.83	-0.82	0
Male high-skilled	-1.54	-0.40	-1.72	-0.44	-0.80	0
Female unskilled	-0.26	-1.05	-0.31	-1.15	-0.82	0
Female medium-skilled	-0.43	-0.96	-0.50	-1.05	-0.82	0
Female high-skilled	-1.54	-0.40	-1.72	-0.44	-0.80	0
Other factors						
Rice and annual crop land	-0.56	0	-0.25	0	-0.12	0
Perennial crop land (avge)	-1.11	0	-0.77	0	-0.78	0
Mobile capital	-1.61	0	-1.57	0		0
Fixed capital (average)	-0.24	0	0.01	0	0.21	0

Note: The model specifies distinct urban and rural labor; in these closures we assume full mobility across locations.

Changes in returns to perennial cropland and to fixed capital are averages over multiple sectors.

**Table 6. Household real consumption (% change from base)**

Household group	Population share (%)	A: Elastic labor supply, no transfers	B: Elastic labor supply, transfers	C: Fixed labor supply, no transfers
Rural				
MH self-employed farm	40.4	-0.26	0.06	-0.09
MH self-employed non-farm	12.2	-0.94	-0.88	-0.74
MH wage-earner	4.2	-0.68	-0.53	-0.54
MH not in labor force	5.0	1.84	2.91	1.99
FH self-employed farm	5.4	-0.01	0.41	0.17
FH self-employed non-farm	2.6	-0.95	-0.91	-0.83
FH wage-earner	0.6	-0.39	-0.10	-0.25
FH not in labor force	3.7	0.38	0.62	0.45
Urban				
MH self-employed farm	3.1	-0.17	0.15	-0.02
MH self-employed non-farm	5.1	-1.31	-1.24	-1.02
MH wage-earner	5.2	-1.17	-1.09	-0.88
MH not in labor force	3.1	2.21	3.65	2.37
FH self-employed farm	0.8	1.09	2.01	1.30
FH self-employed non-farm	3.2	-1.04	-0.91	-0.84
FH wage-earner	1.9	-1.05	-0.95	-0.75
FH not in labor force	3.4	0.32	0.72	0.39

Note: MH: Male-headed household; FH: female-headed household. Not in labor force: retirees, invalids.



**Table 7. Household poverty and inequality changes computed from VHLSS data**

Household group	Pop'n share (%)	Head- count poverty (%)	A: Elastic labor supply, no transfers: headcount (P0), pov. gap (P1), Gini (% change)			B: Elastic labor supply, transfers: headcount (P0), pov. gap (P1), Gini (% change)		
			P0	P1	Gini	P0	P1	Gini
<b>Total</b>	<b>100</b>	<b>19.07</b>	<b>1.48</b>	<b>1.27</b>	<b>0.41</b>	<b>-1.06</b>	<b>-2.88</b>	<b>-0.68</b>
<b>Rural</b>	<b>74.2</b>	<b>21.79</b>	<b>2.24</b>	<b>1.59</b>	<b>0.21</b>	<b>-0.57</b>	<b>-2.21</b>	<b>-0.64</b>
MH self-employed farm	40.4	26.86	2.21	1.99	0.01	-0.66	-1.43	-0.63
MH self-employed nonfarm	12.2	9.48	2.78	0.85	0.07	2.79	-0.17	-0.31
MH wage-earner	4.2	14.80	3.00	2.16	0.72	-3.12	-5.30	-1.00
MH not in labor force	5.0	22.89	1.39	-0.01	0.25	1.01	-0.91	-0.37
FH self-employed farm	5.4	22.31	4.24	0.58	0.26	-2.68	-7.94	-1.34
FH self-employed nonfarm	2.6	12.45	2.32	1.40	0.17	-1.24	-4.03	-0.75
FH wage-earner	0.6	17.67	0.00	0.95	0.44	-4.29	-26.61	-3.64
FH not in labor force	3.7	19.92	-0.48	0.49	0.45	-0.48	-1.78	-0.47
<b>Urban</b>	<b>25.8</b>	<b>11.26</b>	<b>-2.75</b>	<b>-0.85</b>	<b>0.10</b>	<b>-3.80</b>	<b>-7.39</b>	<b>-0.93</b>
MH self-employed farm	3.1	33.02	-1.46	-0.33	0.40	-2.56	-5.90	-1.34
MH self-employed nonfarm	5.1	7.44	-2.35	-2.18	-0.04	0.00	-2.41	-0.58
MH wage-earner	5.2	6.50	2.94	1.69	0.28	0.00	-5.55	-0.83
MH not in labor force	3.1	13.04	-8.18	-1.68	0.03	-0.54	-2.22	-0.56
FH self-employed farm	0.8	24.78	-7.77	-1.17	0.00	-26.26	-45.27	-4.66
FH self-employed nonfarm	3.2	5.86	-5.39	-2.11	-0.03	-7.41	-10.35	-1.00
FH wage-earner	1.9	4.06	-10.15	-1.21	0.44	-23.06	-20.88	-1.31
FH not in labor force	3.4	9.19	0.00	-1.75	0.09	0.00	-2.13	-0.36

Note: MH: Male-headed household; FH: female-headed household. Not in labor force: retirees, invalids.

**Table 8. Changes in aggregate industrial pollution (base case: percent change)**

A: elastic labor, no transfers	
Air pollution	-0.56
Solid waste	-0.39
Water pollution	-0.51

Source: Computed from model results using IPPS (see text for details).

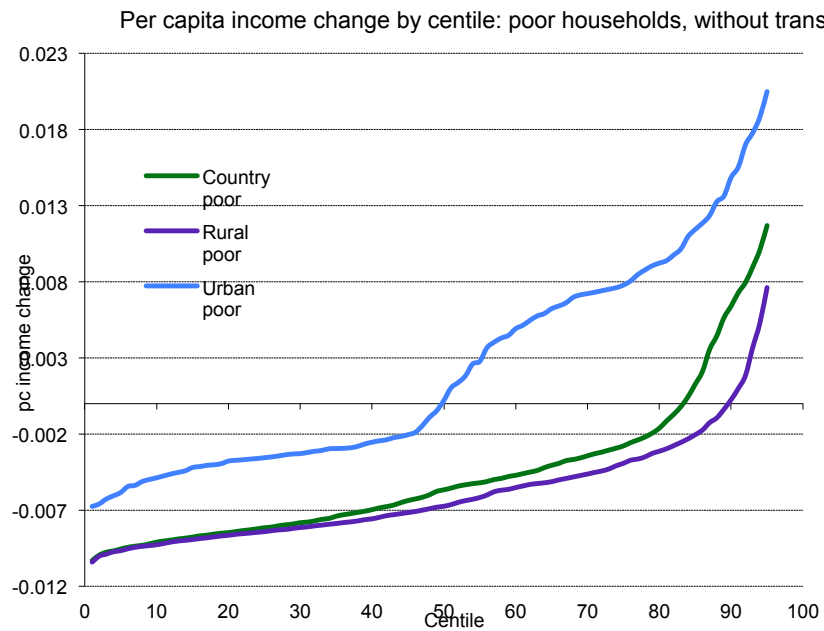


Figure 1: Distribution of p.c. income changes, poor HHs (N=1754), without transfers

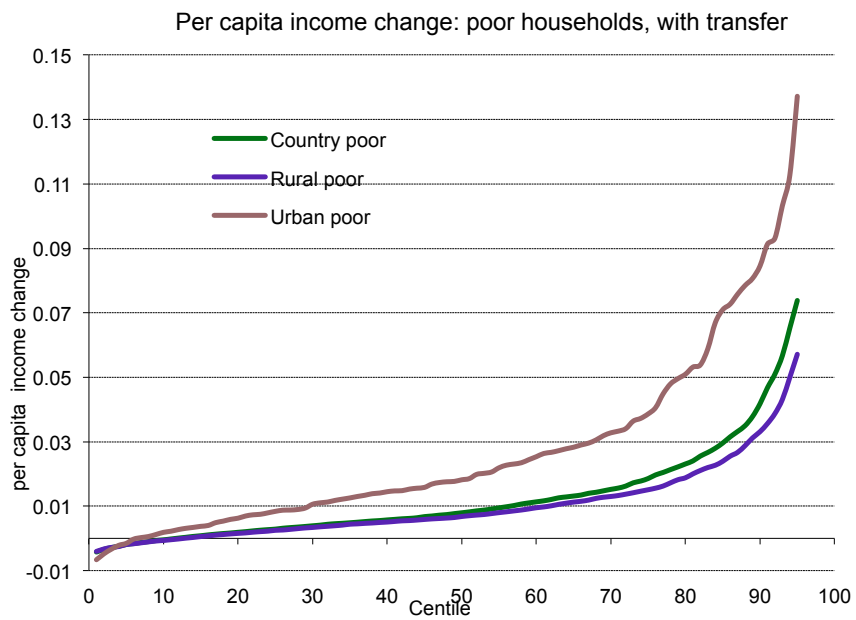


Figure 2: Distribution of p.c. income changes, poor HHs (N=1754), with transfers

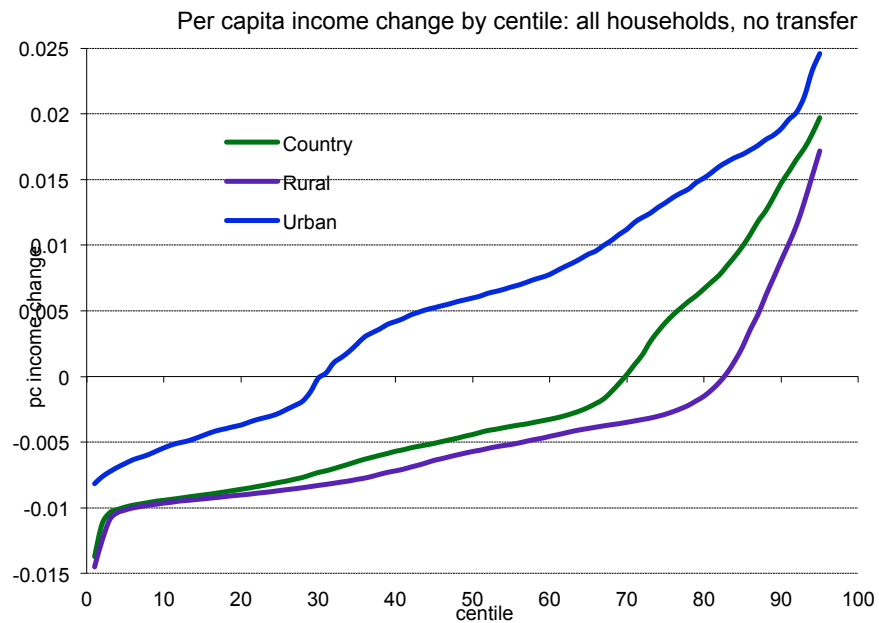


Figure 3: Distribution of p.c. income changes, all HHs (N=9175), without transfers

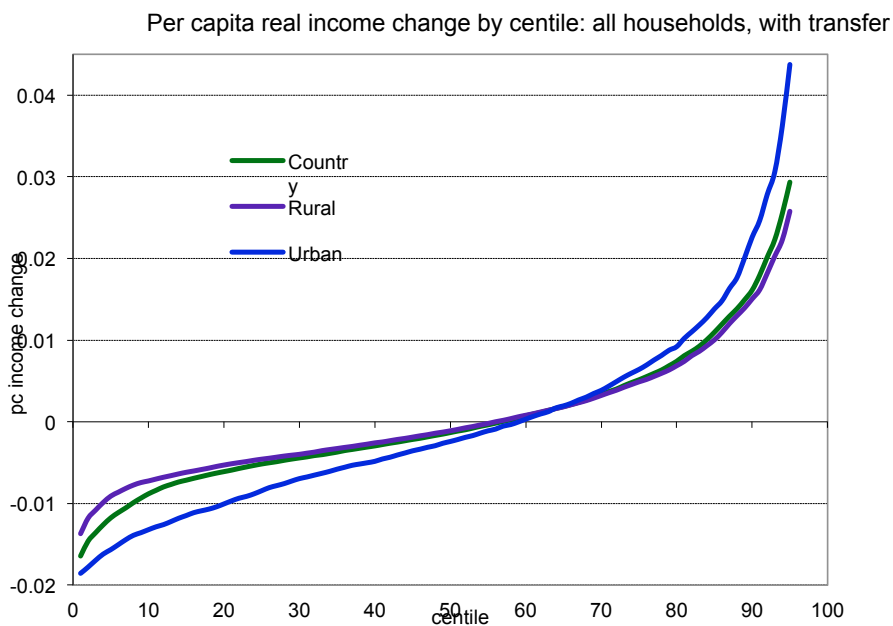


Figure 4: Distribution of p.c. income changes, all HHs (N=9175), with transfers

## Endnotes

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<sup>1</sup> Fullerton and Metcalf (2002) provide a helpful model illustrating these points.

<sup>2</sup> We return to this point in the concluding section of the paper.

<sup>3</sup> Some more recent contributions focus on labor markets using a Harris-Todaro migration structure. See, for example, Daitoh and Omote 2011.

<sup>4</sup> For recent surveys of AGE Models applied to the Vietnamese economy, see Coxhead et al., 2010; and Abbott et al., 2009.

<sup>5</sup> For complete details of the data and mapping strategy see Coxhead et al. 2010.

<sup>6</sup> In structure, our model is a hybrid. It is simultaneous in the behavior of the 16 household categories embedded in the social accounting matrix, but recursive in the mapping from these to the 9,175 VHLSS households. This structure means that we can calculate unique household impacts of each shock in the VHLSS sample, but imposes the assumption that all households within each of the 16 groups respond identically to a given shock.

<sup>7</sup> To our knowledge this is the first application of AGE techniques to the incidence of an environmental policy in Vietnam. El Obeid *et al.* (2002) used a general equilibrium model to examine the structural effects of trade policy reforms and environmental policy initiatives, focusing on measuring changes in emissions of air and water pollution and solid waste, but did not explore welfare and distributional questions.

<sup>8</sup> Only EU and New Zealand currently have carbon taxes. Several developing countries have implemented or are proposing taxes on energy similar to that to be implemented in Vietnam.

<sup>9</sup> Calculated at the rate of VND18,000:US\$1, and with emissions coefficients of (coal) 2,336 kg CO<sub>2</sub>e/tonne; (diesel) 2.68 kg CO<sub>2</sub>e/liter; (gasoline) 2.32 kg CO<sub>2</sub>e/liter. Source for CO<sub>2</sub>e conversions: <http://www.carbontrust.co.uk/cut-carbon-reduce-costs/calculate/carbon-footprinting/pages/conversion-factors.aspx>.

<sup>10</sup> The definition of labor supply and the means of measuring it are both controversial (e.g. Blundell and McCurdy 2008). Among many key issues relevant to our study are the distinction between supply at the intensive margin (hours worked) and at the extensive margin (labor force participation). Moreover, family labor supply differs substantively from that by individuals.

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Preference heterogeneity within families – and across the labor force as a whole – is associated with more elastic labor supply.

<sup>11</sup> Empirically, our search for estimates of labor supply elasticities in developing countries has returned few results. Rosenzweig (1980), using individual data, found inelastic off-farm supply of labor hours by men and women with land, but considerably more elastic supply from landless workers. Using data from Sri Lanka, Sahn and Alderman (1988) find the elasticity of rural labor supply w.r.t. wages of 0.135 (men) and 0.149 (women), with smaller values (0.07 and 0.03) for urban workers. These are based on individuals and apply only to the intensive margin, and so are at the lower bound of such estimates. In more complete analyses, supply elasticities at the extensive margin dominate (in magnitude) those at the intensive margin (Heckman 1993; Blundell and MaCurdy 1999). The latter's surveys of empirical estimates range very widely, with some empirical models yielding values of 1 and even more, especially for women.

<sup>12</sup> The Vietnam SAM provides no guidance on fixed and mobile capital, and our 50-50 division is merely an *ad hoc* assumption. However, robustness checks using 25-75 and 72-25 splits show that the results are not very sensitive to the exact percentage allocations.

<sup>13</sup> This solution approximates expenditure-neutrality to the extent that government expenditures match those by households (Harberger 1962); unlike the theoretical model, however, the match in this AGE is not exact.

<sup>14</sup> Details of the model, database and results are available from the authors.

<sup>15</sup> To illustrate: if the individual household results for real income are aggregated, the default weight for each household will be its share in the group's total initial income. This will mean higher weights applied to real income changes among initially more wealthy households. If factor ownership patterns vary systematically with household income then the aggregate results will be biased toward changes in the fortunes of factors owned more by the rich.

<sup>16</sup> These results are all confirmed in a coterminous study using a smaller but more recent social accounting matrix database. See Willenbockel (2011).

<sup>17</sup> There has been no indication from the Vietnamese government that it intends to pursue a compensating reduction in the rates of non-environmental taxes.