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CONTENTS

Explanatory notes

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AGRICULTURAL TRADE REFORM AND POVERTY IN THE ASIA-PACIFIC REGION: A SURVEY AND SOME NEW RESULTS

*John Gilbert**

We review the literature on the relationship between agricultural trade policy reform and poverty, and the results of recent detailed simulation studies applied to economies in the Asia-Pacific region. We then use the Global Trade Analysis Project model to evaluate the possible impacts of the most recently proposed modalities for agricultural trade reform under Doha on the economies of the Asia-Pacific region, which we compare to a benchmark of comprehensive agricultural trade reform. The current proposal does not result in significant cuts to applied tariffs, and has very modest overall effects on welfare. Average poverty in the region would decrease overall, but the distribution across countries is uneven. By contrast, comprehensive agricultural trade reform, with developing economies fully engaged, tends to benefit most economies in the region in the aggregate, and consistently lowers poverty.

I. INTRODUCTION

Agricultural trade liberalization and its effect on developing economies have long been issues of contention in international trade negotiations, and the Doha Development Agenda is no exception. Key concerns include the potential for aggregate harm through preference erosion, that small economies dependent on food imports would be harmed by rising agricultural prices, and that changes in world prices could have adverse effects on food security and poverty. Concerns over rural poverty led to demands by India and China for enhanced safeguards for

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developing countries in agriculture. In July 2008, the talks collapsed as negotiators failed to reach agreement on this issue.

It is important then, to analyse the likely implications of the Doha Development Agenda proposals on both the economic system as a whole, and on social measures, such as poverty. Several studies have used computable general equilibrium (CGE) for this purpose. Anderson and Martin (2005) assess aggregate welfare, suggesting that most developing economies would gain at the aggregate level from Doha, in particular when they undertake trade reforms themselves and when the full agenda (both agricultural and non-agricultural market access reforms) is considered. The results also indicate that agricultural trade reform is the primary source of global aggregate efficiency gains.

On the poverty side, Hertel and Winters (2006) and the Organisation for Economic Cooperation and Development (OECD) (2006) each recently used a global model to assess aggregate effects of multilateral trade reform (specifically agricultural reform, in the case of the OECD study), and then a series of case studies with models of various specifications built at the national level to explore income distribution issues. Hertel and Winters (2006) include studies of Bangladesh, China, Indonesia and the Philippines. Gilbert (2007) and Panda and Ganesh-Kumar (2008) consider India.

In the present paper, the economic implications of agricultural trade reform under the Doha Development Agenda are assessed, with a focus on the developing economies of the Asia-Pacific region. We first briefly review the current proposal and highlight some key concerns for developing economies. Then we discuss the linkages between trade reforms of the type proposed under the Doha Development Agenda and poverty, and review the latest empirical results for countries in the region. Finally, we present new results from an evaluation of recent modalities at the aggregate level, including poverty impacts, for economies of the Asia-Pacific region.

II. AGRICULTURAL TRADE REFORMS UNDER DOHA

The proposed modalities in agriculture on which we base our analysis were presented at the special session of the Committee on Agriculture on 17 July 2007. The document sets out formulas for cuts in the areas of domestic support, market access (tariffs) and export competition, in addition to treatments of sensitive products, safeguards and related issues (WTO 2007).[1] Key features of the proposal

[1] A further revision of the Draft Possible Modalities on Agriculture was released in July 2008. However, the amendments have focused more on technical issues; the big-picture numbers on required cuts remain largely unchanged.

are set out in detail in the annex. Briefly, it calls for cuts of 45 to 70 per cent in bound tariffs and domestic support in developed economies, with lower commitments for developing economies, and elimination of export subsidies. While the proposals appear ambitious, there are several areas of contention. First, how much actual liberalization will occur? Second, how much flexibility will developing countries have in dealing with the consequences of reform? And third, how will economies be affected by the erosion of preferential access?

On the first issue, tariff overhang (where the bindings on tariffs are significantly higher than the actual applied rates) and limited binding coverage (where only a proportion of tariffs are actually bound) mean that commitments to cuts made on bound tariffs could leave actual distortions at high levels. A summary of current applied and bound tariff rates is presented in table 1. This issue is discussed further in Laborde, Martin and van der Mensbrugghe (2008).

Table 1. Tariffs in agricultural/food products for Asia-Pacific and other economies circa 2006
(Percentage)

Country/region/area	Year	Applied tariff		Bound tariff		
		Weighted average	Standard deviation	Weighted average	Standard deviation	Binding coverage
Agriculture						
Australia	2006	0	1	3	4	100
New Zealand	2006	0	2	1	4	100
China	2005	10	9	16	9	100
Hong Kong, China	2006	0	0	0	0	98
Japan	2006	2	6	3	7	100
Republic of Korea	2004	200	123	167	130	99
Indonesia	2006	1	3	34	9	100
Malaysia	2005	1	6	8	13	100
Philippines	2005	7	10	34	14	97
Singapore	2005	0	0	10	1	100
Thailand	2005	11	18	36	25	98
Viet Nam	2005	11	15	–	–	0
Bangladesh	2006	3	10	158	56	94
India	2005	31	27	87	37	100
Sri Lanka	2006	17	13	49	4	96
Russian Federation	2005	7	5	–	–	0
Canada	2006	0	6	1	7	100

Table 1. *(continued)*

Country/region/area	Year	Applied tariff		Bound tariff		
		Weighted average	Standard deviation	Weighted average	Standard deviation	Binding coverage
Mexico	2005	3	12	34	11	100
United States of America	2006	2	44	5	49	100
European Union	2006	2	4	4	5	100
All countries	2006	10	25	24	47	77
Food products						
Australia	2006	1	2	5	5	100
New Zealand	2006	1	3	10	9	100
China	2005	12	10	12	11	100
Hong Kong, China	2006	0	0	0	0	100
Japan	2006	8	10	10	10	99
Indonesia	2006	9	45	73	28	100
Malaysia	2005	4	7	14	21	93
Philippines	2005	7	12	31	9	84
Republic of Korea	2004	29	102	38	107	94
Singapore	2005	0	0	8	2	100
Thailand	2005	10	17	36	29	99
Viet Nam	2005	27	26	–	–	0
Bangladesh	2006	12	7	193	43	81
India	2005	66	51	186	60	87
Sri Lanka	2006	21	14	48	4	94
Russian Federation	2005	11	5	–	–	0
Canada	2006	1	4	5	16	100
Mexico	2005	5	19	37	8	100
United States of America	2006	2	14	4	23	100
European Union	2006	4	7	9	9	100
All countries	2006	8	40	24	65	73

Source: Data from the Trade Analysis and Information Systems database of the United Nations Conference on Trade and Development, available at http://r0.unctad.org/trains_new/index.shtm by subscription only.

On the second issue, special and differential treatment is the principle that developing countries have special needs and should not be subject to the same commitments as developed economies. In the proposal, the requirements for developing economy liberalization are lower, and least developed countries (LDCs) are not required to liberalize at all. While this grants extra flexibility, it also limits the scope for efficiency gains within those economies. Exceptions for sensitive

products have also been high on the agenda. From a developing economy perspective, this is a concern if developed economies use such restrictions to shield the products in which developing economies are most competitive. But developing countries, in particular India and China, have also sought latitude to subject a set of products to reduced disciplines on the grounds that certain products are particularly important for livelihoods or for food self-sufficiency. It is possible that exemptions for sensitive products could lead to many of the most highly protected markets remaining untouched under the Doha Development Agenda package (see Jean, Laborde and Martin 2005).

Preference erosion refers to the effect that lowering barriers to other countries has on those who already have preferential access to developed country markets through a variety of schemes, including the Generalized System of Preferences and a series of provisions within the European Union and the United States of America. Despite recent evidence suggesting that the utilization rate of such preferences is quite low (UNCTAD 1999), this remains a major issue.[2] As Anderson and Martin (2005) note, these schemes may reduce demands from preference-receiving countries for agricultural reform in developed economies, but at the same time worsen the positions of other countries excluded from such programmes.

III. ASSESSING POVERTY LINKAGES OF AGRICULTURAL TRADE REFORM

To assess the potential impact of Doha on the region we need a conceptual framework. Trade theory provides solid predictions on the aggregate consequences of agricultural trade reform. One such consequence is the likelihood that average world prices of food and agricultural products will rise. In developing economies that are net exporters of food and agricultural products (for example India, Indonesia, Malaysia and Thailand, see table 2), we might expect the aggregate effect of an increase in agricultural prices to be positive, ceteris paribus. On the other hand, in developing economies in the region that are net importers of food and agricultural products (for example Bangladesh and the Philippines), we might expect the aggregate effect to be negative, ceteris paribus, although this may change depending on exact sectoral price shifts.

[2] The more recent work of Francois, Hoekman and Manchin (2006) reaches similar overall conclusions, and suggests that preference erosion is primarily a bilateral issue, as utilization rates are significant in only a few cases, usually with respect to the European Union. Similarly, Low, Piermartini and Richtering (2006) find the risk of preference erosion is small on average and limited to a small number of sectors.

Table 2. Base pattern of trade/production in agricultural/food products for Asia-Pacific and other economies, 2001

Country/region	Imports	Exports	Production	Net exports	Self sufficiency
	millions of United States dollars)				(percentage)
Agriculture					
Australia	624	8 340	24 071	7 716	132
New Zealand	279	1 720	7 143	1 441	120
China	12 006	7 265	279 963	-4 741	98
Hong Kong, China	2 431	17	2 159	-2 414	-12
Japan	16 194	1 275	71 768	-14 919	79
Republic of Korea	4 958	580	27 153	-4 378	84
Indonesia	2 310	2 445	21 935	135	101
Malaysia	2 275	1 173	3 545	-1 102	69
Philippines	1 100	783	17 162	-317	98
Singapore	1 537	548	689	-989	-44
Thailand	1 593	2 922	14 450	1 329	109
Viet Nam	333	1 195	6 050	862	114
Bangladesh	1 020	131	12 534	-889	93
India	2 374	3 209	138 120	836	101
Sri Lanka	394	924	4 503	530	112
Russian Federation	3 011	888	29 330	-2 124	93
Canada	4 856	9 588	25 205	4 732	119
Mexico	5 661	4 057	34 786	-1 603	95
United States of America	19 235	33 662	206 040	14 427	107
European Union	72 192	44 178	260 956	-28 015	89
South and Central America	8 708	27 588	137 102	18 881	114
Rest of world	29 915	24 366	417 596	-5 549	99
Food products					
Australia	2 606	10 444	35 301	7 837	122
New Zealand	960	6 596	11 045	5 636	151
China	5 971	9 634	170 843	3 663	102
Hong Kong, China	4 943	361	4 911	-4 582	7
Japan	34 842	2 318	310 018	-32 524	90
Republic of Korea	5 432	2 044	43 102	-3 389	92
Indonesia	1 829	4 585	33 997	2 757	108
Malaysia	2 870	5 501	9 742	2 632	127
Philippines	2 439	1 572	21 120	-867	96

Table 2. *(continued)*

Country/region	Imports	Exports	Production	Net exports	Self sufficiency
	millions of United States dollars)				(percentage)
Singapore	3 150	2 333	4 340	-816	81
Thailand	2 926	9 984	23 820	7 059	130
Viet Nam	1 227	1 858	5 483	630	112
Bangladesh	927	322	10 530	-605	94
India	2 297	3 822	50 463	1 525	103
Sri Lanka	389	131	1 501	-259	83
Russian Federation	7 899	3 101	31 409	-4 798	85
Canada	9 176	11 264	56 527	2 089	104
Mexico	5 778	4 202	105 080	-1 576	99
United States of America	35 522	32 551	754 507	-2 971	100
European Union	137 037	137 280	812 591	244	100
South and Central America	13 994	32 680	221 491	18 687	108
Rest of world	44 214	25 797	359 719	-18 417	95

Source: Dimaranan, B.V. (2006).

To assess poverty is more difficult. Winters (2002) identifies seven linkages between trade reform and poverty: changes in (a) consumer prices and availability of goods; (b) factor prices and quantities employed; (c) taxes and transfers influenced by shifts in tariff revenue; (d) the terms of trade and other external shocks; (e) investment and innovation that affect the long-run growth path; (f) remittances; and (g) short-run risk and adjustment costs.

At a fundamental level, changes in international trade policy affect relative prices. Changes in relative prices drive changes in the returns paid to factors of production, which are owned by households in varying proportions. Factors may also have to absorb adjustment costs in the short run. Trade reform therefore alters both the pattern of household income and the prices faced by households. Changes in revenue may affect incomes directly or indirectly as other sources are adjusted to make up lost tariff revenue. Again, theory provides some guidance. The Stolper-Samuelson theorem (1941) would predict an increase in the return to factors used intensively in agriculture, for example land and agricultural labour. Since in many cases these factors are "owned" by the rural poor, we might expect to see an improvement in the incomes of those groups. On the other hand, the increase in price may negatively affect those who spend a significant fraction of their income on food product (the urban poor, for example).

The picture may be clouded when we consider not only the effect that agricultural trade reform in developed countries may have on developing countries through changes in world prices, but also the direct effect of tariff reform within the developing countries themselves. In many developing economies in the region, the average tariff on agricultural products remains high. As Winters (2002) notes, this provides an avenue for importing economies to combat the effect of world price rises. If tariff reductions are significant, it is possible that domestic agricultural prices may fall even as world prices rise, tending to hurt the owners of agricultural factors (and benefit those who spend a high fraction of their income on food products).

Distortions within the economic system may further alter the predictions of the classical theory. Hence, for example, if there are restrictions on the degree of labour mobility, owners of labour may be prevented from moving to the activities in which their primary resource is most valued, increasing the potential for negative impacts on those groups. On the other hand, if there is unemployment or underemployment in the economic system, it is possible for trade reform to have employment-expanding effects which may have a positive impact on, for example, the urban poor.

IV. RESULTS OF RECENT COMPUTABLE GENERAL EQUILIBRIUM ANALYSES

Beyond the broad ideas outlined in the preceding section, applying theory to real-world examples of trade reform is a complex task. As we move beyond simple models, the predictions of theory with regard to factor price movements are weak, and depend on the exact structure of production. Moreover, real-world economic systems vary considerably, and are riddled with a multiplicity of distortions. Hence, to assess the implications of reform requires quantitative techniques. As Winters, McCulloch and McKay (2004, 73) simply put it: "Outcomes depend on the specific trade reform measures being undertaken, and the economic environment in which they take place".

Quantitative analyses of the poverty impacts of trade reform can be divided into two literatures. Ex post analyses look at cases of reform in the past and try to ascertain the effect that the reform had. Ex ante analyses try to predict what the effect of a proposed reform will be before the reform has occurred. Winters, McCulloch and McKay (2004) surveyed ex post analyses of the impacts of unilateral trade reform, concluding that the evidence supports the view that trade liberalization

will reduce poverty in the long run and on average, although there can be no simple and general conclusions.[3]

Hertel and Reimer (2005) review ex ante studies and provide a method of classification by simulation type: partial equilibrium models, general equilibrium models, and micro/macrosimulation models that combine macrolevel simulation with microlevel household models. They conclude that CGE techniques and micro/macro methods have the best potential for fully evaluating the complex web of determinants of changes in poverty. CGE models are numerical models based on general equilibrium theory. They turn abstract models of theory into a practical tool for policy analysis. A number of features distinguish CGE. The models are multisectoral, and in many cases multiregional, and the behaviour of economic agents is modelled explicitly through utility and profit-maximizing assumptions. In addition, economy-wide constraints are rigorously enforced. Distortions in an economic system will often have repercussions beyond the sector in which they occur. By linking markets, CGE techniques are effective at capturing feedback and flow-through effects.

One of the more popular current CGE models is the Global Trade Analysis Project (GTAP) created and maintained by the Center for Global Trade Analysis at Purdue University. This model is a multiregional, competitive, Armington trade model.[4] The code for the model is publicly available, as is the database on which the model is built. This allows simulation results to be replicated, and the model is in widespread use. It can be considered the current benchmark model in the literature. For detailed discussion of CGE models and recent surveys of their application, see Scollay and Gilbert (2000), Gilbert and Wahl (2002), Robinson and Thierfelder (2002), Lloyd and MacLaren (2004) and Hertel and Winters (2005).

In terms of trade reform and poverty, most of the attention in the CGE literature so far has been on the two largest developing economies in the Asia-Pacific region, namely, China and India.[5] Kuiper and van Tongeren (2006) consider the poverty/income distribution aspects of Doha for China, as do Zhai and Hertel (2006). Both of these studies use different and quite innovative techniques.

[3] Goldberg and Pavcnik (2007) provide a similar conceptual framework to Winters (2002), and have also surveyed the ex post analyses of the impact of globalization on income distribution. They find a contemporaneous increase in globalization and inequality in most developing countries, but also conclude that establishing a causal link between these two trends is challenging.

[4] An Armington model replicates intra-industry trade flows by assuming that goods in the same product category from different countries are imperfect substitutes.

[5] Bandara (2007) also surveys recent Doha simulation results with a focus on the Asia-Pacific region, but in terms of aggregate welfare effects rather than poverty.

Kuiper and van Tongeren (2006) take a village modelling approach. Rather than considering a complete set of households within the national economy, they use a general equilibrium model of a single farming village. The model differs from standard CGE approaches in that the production and consumption decisions are not separable, they are made jointly by the individual farm households. They distinguish four groups of households, using ownership of draft power and access to outside employment as grouping criteria. The resulting groups represent households with differential capacity for earning a living from agriculture and from migration to urban areas.

The model is integrated with the results from the GTAP model, which generates global price shocks and changes in wages outside the village. A "Doha liberalization scenario" and a comprehensive trade reform benchmark are considered. Under the Doha scenario, the model projects average income gains within the farm village in the region of 5 per cent, with ownership of capital in the form of draft power a defining factor in determining the distribution of the gains from price changes, and engagement in non-farm activities the defining factor in gains from employment. The results also suggest a widening income inequality, in particular between those with access to outside employment opportunities (tied to migration) and those without, as the latter group have fewer opportunities for adjustment.

Zhai and Hertel (2006) use a model distinguishing 53 productive sectors and 100 households (40 rural and 60 urban). It is a competitive Armington-type model, and is used in conjunction with GTAP for global impacts. Interesting features of the model include imperfect labour mobility and rural-urban migration, both of which are important characteristics of the rural-urban divide in China. The model identifies several labour categories (unskilled, semi-skilled and skilled), with rural and urban workers distinguished and imperfectly substitutable in production (an indirect means of building geographic dispersion into the model). The model is benchmarked to a 1997 base year, and is updated through recursive dynamic simulation to 2005—prior to the trade reform simulations. The trade reform scenarios (Doha and several other benchmarks) are run as comparative statics with a steady-state closure. In this approach, the rental rate on capital is held constant and the adjustment of stock of capital is allowed, in an attempt to approximate capital accumulation effects.

In terms of poverty, Zhai and Hertel (2006) report that the urban-rural income ratio declines in all global trade liberalization scenarios, although the magnitude of this change is small. There is no change in inequality within the urban and rural areas. Poverty headcount ratios decline for all household groups. The results of Zhai and Hertel (2006) also suggest that the largest increases in welfare following global trade liberalization and Doha would accrue to rural

households, which benefit from the fact that returns to agricultural land increase relative to other factor prices.

In the case of India, there are two recent studies.[6] Gilbert (2007) considers the impact of the current proposed modalities for reform in agriculture only under Doha at the household level for India, in addition to more comprehensive agricultural reform. The study uses the GTAP model to estimate the world market effects, after first modifying the underlying GTAP6 data to reflect the latest available applied protection levels (using the Trade Analysis and Information System (TRAINS) database of the United Nations Conference on Trade and Development). The global results are then fed into a single-economy CGE model of India.

The India model identifies 43 productive sectors and five factors of production, along with nine households (four rural and five urban). Household data are obtained from Pradhan and Sahoo (2006) and matched to the GTAP data on aggregate consumption, production and trade. The simulations are run as comparative statics, with two different adjustment time horizons (short- and long-run) represented by mobility/immobility of capital across productive sectors. Tax replacement is (implicitly) through lump-sum transfers from the households. Parametric sensitivity is addressed with unconditional analysis of the trade elasticities, implemented using Monte Carlo (stochastic simulation) techniques, with the distributions of underlying parameters based on Hertel and others (2007).

Under the Doha scenarios, the welfare of the poorest households (agricultural labour and other rural labour) falls, while the welfare of the richest group (urban self-employed) rises, in both the short and long run. The income of the rural self-employed (landowners) also rises under the Doha scenarios, suggesting that ownership of land and capital helps to insulate this group from the terms of trade shifts. The result is similar to that of Annabi and others (2006) for Bangladesh, but the change is not robust to variation in the model parameters. Under comprehensive reform, the results are quite different. The aggregate welfare gains are several orders of magnitude larger, and income of all households except the rural self-employed rises. The results are robust to variation in the model parameters, and suggest that the landowning class in India is able to benefit from rising world prices under Doha reform when India does not engage in significant reforms of its own, but faces considerable falls in income if domestic prices are allowed to fall (in the long run, the fall in the return to agricultural land is estimated at 10 per cent).

[6] Polaski and others (2008) do not directly consider Doha, but do consider the impact of price changes in agricultural commodities. They find that a decrease in the price of rice could have a significant negative impact on Indian poverty levels.

Overall, the results suggest that India would gain from agricultural reform, but that a small increase in rural poverty is possible under the Doha agreement as it stands. On the other hand, comprehensive reform is likely to increase the incomes of the poorest groups, but at the expense of a slight increase in income inequality, and a substantial reduction in the incomes of landowners.

Panda and Ganesh-Kumar (2008) specifically consider the issue of food security. Their modelling approach is very similar to that used in Gilbert (2007), with the exception that they use the MIRAGE model developed by the International Food Policy Research Institute rather than GTAP as the source of their global price changes. They consider a Doha scenario, and find that all households experience a rise in welfare, and a decline in poverty. However, they argue that this does not necessarily translate into increased food security, in the sense that the poorest households decrease their consumption of protein and calories, while increasing consumption of fats. These conclusions are based on an ex post assessment of the household consumption patterns which drive the CGE model.

As an example of a smaller South Asian economy, results for Bangladesh are available from Annabi and others (2006). This study uses the GTAP model to estimate the overall effect of trade reform under the Doha proposals (both agriculture and non-agriculture) at the world level, and then inputs the world market effects into a single-economy CGE model for Bangladesh. The single country model is used to generate detailed results at the household level. The study also considers the potential impact of more comprehensive global reform, and of unilateral reform by Bangladesh.

The simulation procedure is recursive dynamic, with growth of the labour stock and productivity at fixed levels, and the capital stock growth path endogenized by a simple investment rule that is sector specific. Tax replacement is (implicitly) through lump-sum transfers from the households. The simulations extend for a 20-year period; comparisons are made relative to a baseline growth path. The results indicate aggregate welfare losses for Bangladesh under the Doha scenarios, along with small increases in the headcount ratio (diminishing somewhat but remaining negative in the long run). The negative aggregate welfare effect is driven by adverse terms of trade movements. These remain even in a scenario with complete liberalization in the rest of the world. The poverty effect is driven by increased prices, even as nominal unskilled wages rise slightly. When broken down to the household level, Annabi and others (2006) find poverty increases for all household categories except large farmers.

Within the Association of Southeast Asian Nations, studies have been undertaken for Indonesia, the Philippines and Viet Nam. The Robilliard and Robinson

(2006) study of Indonesia uses a set of three models to estimate poverty effects (the only one to do so in that country). At the top level, the GTAP model is used to estimate the overall effect of trade reform under the Doha proposals (agriculture and non-agricultural market access) at the world level. The world market effects are then used as input into a single-economy CGE model for Indonesia. At the third level, a detailed microsimulation model is used to estimate household results. In addition to Doha, the authors consider comprehensive global reform and unilateral reform within Indonesia as benchmarks.

The Indonesia CGE model identifies 21 productive sectors and 15 productive factors (land, plus eight types of labour and six types of capital). The model does not identify different households. It attempts to characterize the dual nature of the Indonesian economy by distinguishing between formal and informal activities in each sector. The two subsectors differ in the type of factors they use, and consumers purchase a composite of formal and informal production of the same commodity (i.e., an Armington-type specification). Also of note is the characterization of rural and urban labour as separate factors of production, which implies that rural workers cannot shift out of rural production activities. The simulations are comparative static, with a medium/long-run time frame represented by mobility of capital across economic activities. Prices, wages and aggregate employment variables from the CGE model are used as input to a microsimulation model that generates changes in individual wages, self-employment incomes and employment status. The microsimulation model is based on household and individual level data from the survey data for the year 1996 and simulates income generation mechanisms for 9,800 households.

The Doha scenario results indicate very small impacts on Indonesia, at just a 0.1 per cent impact on per capita consumption and less than a 1 per cent rise in aggregate imports and exports. There is a negligible impact on inequality, but rising incomes boost a small number of people out of poverty (about 50,000). By contrast, the results of the unilateral liberalization scenario indicate an increase in the average per capita household income of 0.6 per cent and a decrease in the headcount ratio from 18.3 down to 18.1 per cent, with the greatest impact on urban households. Full global reform generates still larger results, pulling an estimated 1.7 million out of poverty, although this scenario must be regarded as a benchmarking exercise more than a realistic outcome of current negotiations.

The impact of the Doha proposals (agriculture and non-agriculture) on the Philippines is analysed in Cororaton, Cockburn and Corong (2006). Again, the study uses the GTAP model to estimate the overall effect of trade reform under the Doha proposals at the world level, and then inputs the world market effects into a single economy CGE model for the Philippines. The latter model is then used to

generate household level results.[7] In addition to the Doha scenarios, the authors also consider comprehensive global reform and unilateral reform within the Philippines as benchmarks. Tax replacement (making up the lost tariff revenue through alternative policy interventions) is considered using indirect taxes and income taxes.

The Philippines model identifies 35 productive sectors and six productive factors, with agricultural labour distinguished from non-agricultural labour and mobile only across agricultural sectors. Twelve household categories are distinguished, six each of rural and urban. The simulations are comparative static, with a short-run adjustment time horizon represented by specificity of capital across productive sectors.

Cororaton, Cockburn and Corong (2006) estimate increases in income for all household groups under the Doha scenario, with roughly equal gains, on average, to rural and urban households. However, they do not present a household welfare measure, so it is unclear whether households are better off in real terms. Poverty calculations by the authors suggest that perhaps they are not, as poverty increases slightly under the Doha scenario. The authors argue that the deterioration is due to the fact that consumption prices rise more, on average, than household nominal incomes, primarily due to deterioration in the terms of trade. In general, rural households are somewhat more affected than urban households. When considering the results of comprehensive global agricultural reform on poverty levels in the Philippines, Cororaton, Cockburn and Corong (2008) find a positive, though modest, effect.

Finally, Viet Nam, as a newly acceded member of the World Trade Organization, will not be required to make further cuts under the current Doha Development Agenda proposals. Nonetheless, it will be affected by reforms in other countries. Studies are limited, but Linh, Burton and Vanzetti (2008) have recently considered the possible impact of a Doha scenario using GTAP combined with an estimated household demand model for farm households in Viet Nam. The scenario is quite rudimentary: a 50 per cent reduction in tariffs/export subsidies and domestic support across the board, and a complete elimination of all barriers (a comprehensive benchmark). They consider the possibility of unemployment. Their main finding is that comprehensive global reform is likely to raise the welfare of farm households.

[7] Cororaton, Cockburn and Corong (2008) use the same regional model in combination with the World Bank's LINKAGE model to analyse the implications of global agricultural reform.

V. GLOBAL TRADE ANALYSIS PROJECT RESULTS BASED ON NEW MODALITIES

To further analyse the implications of the recent Doha modalities on the economies of the Asia-Pacific region, we take an approach similar to that used in Anderson, Martin and van der Mensbrugghe (2006), using the GTAP model. The GTAP model uses the GTAP6 database (Dimaranan 2006), which is the most recent and comprehensive data of its kind available. It has a base year of 2001. While GTAP6 identifies 87 regions and 57 sectors, as a practical matter it is necessary to aggregate. Because the database does not have comprehensive measures of services protection, we have chosen to aggregate the services sectors, while maintaining the greatest possible degree of sectoral detail in agriculture and manufactures. The regions are aggregated to 22, with a focus on the economies of the Asia-Pacific region.

Before undertaking our analysis of the Doha scenario, we first updated the agricultural protection data in GTAP6 to the latest available applied levels, using information in the TRAINS database. This is undertaken to give a more realistic picture of the actual level of agricultural protection in the region.[8] After updating the tariff data, we consider the effect of the agricultural trade reform described in the annex. The required tariff cuts are calculated on the basis of the latest bound rates in TRAINS, adjusted for binding coverage, and are assumed not to take effect if post-cut rates are above current applied levels. Export subsidies in agriculture are eliminated and domestic support measures cut by 60 per cent for developed economies and 40 per cent for developing countries. Viet Nam, as a newly acceded member, is assumed not to make any further commitments. Accession by the Russian Federation is assumed, and it also does not make any further commitments. Bangladesh, as an LDC, is exempted from cuts and the recipient of zero agricultural tariff preferences from developed economies. In the light of the fact that the Republic of Korea declares itself as a developing economy under the World Trade Organization, its commitments are those of a developing economy.

In order to gain some sense of the significance of our results, it is useful to have a benchmark simulation with which they can be compared. Earlier work (for example, Anderson, Martin and van der Mensbrugghe 2006) has used global

[8] GTAP6 data is drawn from MacMaps, and while older (based on 2001), it does have some significant advantages over the raw data in TRAINS, in particular with respect to identifying preferential tariffs. Because of the risk of incorrectly replacing preferential rate with higher most favoured nation rates, where GTAP6 indicates that the applied tariff is lower than recorded in TRAINS, we leave it in place.

liberalization of merchandise trade as a benchmark. Given our focus on agricultural trade reforms, we run an alternative benchmark of comprehensive agricultural liberalization. In this scenario all tariffs, export subsidies and domestic support in agricultural and food products are eliminated. The running of this scenario is not meant to suggest that this is a likely outcome of current global negotiations.

Both scenarios (Doha and comprehensive) are run as comparative statics. The results should be interpreted as representing the change in the economic system that would occur given the proposed shock, with sufficient time to adjust to the new equilibrium. The model does not identify the path taken. We allow capital to adjust by reallocating across sectors, making our analysis medium/long-run.

Aggregate welfare

Table 3 presents the aggregate welfare results from our scenarios, using the equivalent variation measure.[9] The first result is that the magnitude of the estimated welfare gains is modest, at around $5.2 billion globally. Of this, approximately one third accrues to developing economies in the Asia-Pacific region. It should be reiterated that we are considering only agricultural trade reform here, and not the full Doha trade reform agenda. Nonetheless, agriculture is among the most protected sectors of economies in the region, and is a major part of the agreement. The small aggregate gains reflect the relatively small degree of actual reform that is anticipated if the proposal on agriculture remains in its current form. That is, given the degree of binding overhang, the current proposal in most cases results in only small reductions in the actual applied tariffs of the economies in the model. If sensitive products are excluded, as discussed in Jean, Laborde and Martin (2005), the potential for economically significant gains to arise from agricultural reform could be eroded even further.[10]

To gain perspective on the potential efficiency gains left on the table by the currently proposed modalities, we consider the welfare estimates from comprehensive agricultural trade reform. In this case, the estimated global welfare gains exceed $37 billion in the long run. These figures are seven times larger than the corresponding estimates for the Doha scenario. This clearly indicates just how

[9] Equivalent variation is the monetary value of the increment in income that would have to be given to (or taken away from) a household at today's prices to make it as well off today as it would be under the proposed policy change. The changes are sometimes called a "one-off" gain/loss, but this is somewhat misleading, since the changes are permanent.

[10] It is also worth noting that GTAP data does suffer from aggregation bias. The weighted average tariffs in the database may not adequately reflect the potential for gains from elimination of peaks at the tariff line level.

much reform is left undone by the current modalities. For developing economies in the Asia-Pacific region, the contrast is particularly sharp. These countries would gain (in aggregate) roughly 10 times more from comprehensive reform than from the current Doha proposals.

Not all countries are expected to gain from agricultural trade reform, in either scenario, and in fact the gains from the Doha scenario in particular are quite uneven across regions. In order to understand the distribution of the welfare gains and losses across different regions, it is useful to go back to basic economic theory. The welfare effect of reform can be broken down into two components: the allocative efficiency effect and the terms of trade effect. The former is the impact of reallocating resources across economic activities. As an economy removes its own barriers, this effect is generally positive.[11] The terms of trade effect is the result of changes in the world price. For a country engaging in its own tariff liberalization, this effect is negative, ceteris paribus, and increases along with the economic size of the country (that is, the degree of market power).[12] The overall impact of own reform will be determined by the balance of these two factors, with allocative efficiency dominating when the degree of reform is large, and terms of trade dominating when the economy is large and/or the degree of tariff reform small. The liberalization of other countries is also reflected in the terms of trade; when country A lowers its barriers to country B, the terms of trade of country B improve.

Table 3, which also presents a breakdown of equivalent variation into its allocative efficiency and terms of trade components, could be reconsidered with the above ideas in mind. Some countries in the region are likely to be large gainers from positive external shifts in the terms of trade that they face. These are countries that have a strong comparative advantage in agricultural products (reflected in their position as net exporters in table 2). Such economies include Australia and New Zealand, who are the largest beneficiaries in proportional terms. Other net importing economies benefit substantially from their own reform as the benefits of increased efficiency outweigh the negative effects of terms-of-trade shifts. The two primary examples of this type are Japan and the Republic of Korea. Thailand benefits from both increased efficiency as a result of lowering its substantial tariffs, and from positive terms of trade shifts from improved market access, as does India (although the effects are proportionally much smaller).

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[11] It is possible for allocative efficiency effects to be negative when there are other distortions in the economic system (such as taxes on other activities).

[12] Where the liberalization involves removing export subsidies, as opposed to tariffs, terms of trade movements are positive, ceteris paribus, and increase along with the economic size of the country.

Table 3. Estimated aggregate welfare effect of agricultural trade reform

Country/area	Doha scenario				Comprehensive scenario			
	EV	AE	TOT	Percentage of GDP[a]	EV	AE	TOT	Percentage of GDP[a]
	(millions of United States dollars)				(millions of United States dollars)			
Australia	755	11	745	0.21	2 146	84	2 061	0.60
New Zealand	325	-13	337	0.64	506	-19	525	1.00
China	-441	-115	-326	-0.04	-919	-189	-730	-0.08
Hong Kong, China	-4	-1	-3	0.00	201	6	196	0.12
Japan	2 117	2 908	-790	0.05	17 614	19 781	-2 167	0.42
Republic of Korea	955	1 176	-221	0.22	2 113	3 160	-1 046	0.49
Indonesia	-54	-15	-38	-0.04	-26	-127	101	-0.02
Malaysia	-23	18	-41	-0.03	831	76	754	0.94
Philippines	-38	-30	-8	-0.05	-73	50	-123	-0.10
Singapore	23	4	19	0.03	17	9	8	0.02
Thailand	156	76	80	0.14	416	268	148	0.36
Viet Nam	-13	-9	-4	-0.04	44	39	4	0.13
Bangladesh	-28	-3	-25	-0.06	-19	58	-77	-0.04
India	95	41	54	0.02	844	1 392	-548	0.18
Sri Lanka	4	4	0	0.02	116	7	109	0.73
Russian Federation	-274	-179	-95	-0.09	109	322	-213	0.04
Canada	71	-155	226	0.01	442	507	-65	0.06
Mexico	-144	270	-414	-0.02	-126	721	-847	-0.02
United States of America	1 483	405	1 079	0.01	2 692	923	1 768	0.03
European Union	1 197	1 662	-466	0.01	7 588	6 811	777	0.09
South and Central America	466	39	427	0.03	263	389	-126	0.02
Rest of World	-1 416	-872	-544	-0.06	2 340	2 911	-571	0.09

Source: Global Trade Analysis Project simulations by author.

Abbreviations: AE allocative efficiency component of equivalent variation
EV equivalent variation
GDP gross domestic product
TOT terms of trade component of EV

[a] Percentage of GDP = equivalent variation as a percentage of base GDP

Most of the other developing economies in the region are estimated to bear negative overall welfare effects of reform under Doha, although the magnitudes are small.[13] In all cases this is a consequence of adverse terms of trade movements, suggesting that rising agricultural prices under Doha would be harmful in aggregate to many developing economies in the Asia-Pacific region (excepting India, the Republic of Korea and Thailand), although by small margins.

[13] To put the measures in perspective, we have provided equivalent variation as a proportion of the initial gross domestic product levels.

The case of Bangladesh is interesting because as an LDC it is not required under the current proposal to make any commitments to reciprocal multilateral trade liberalization. Moreover, as an LDC it is the recipient of preferential access in agriculture to all developed economies. We might normally expect the latter to be reflected in a positive welfare effect through shifts in the terms of trade, but our results do not bear out this expectation. The aggregate effect on Bangladesh, while small, is negative, and appears to be driven by terms of trade shift. This suggests that tariffs faced by Bangladesh in the developed world are already low, and there is little to be gained in aggregate from preferential access. Rather, Bangladesh is hurt as world prices rise (it is a net importer of both agricultural and food products, as shown in table 2) and/or through preference erosion as barriers to other countries are lowered.

How could Bangladesh and similar economies counteract this effect? It is possible that allocative efficiency improvements could counter terms of trade movements if such economies were to liberalize their own relatively high (see table 1) tariffs in agriculture and food products. This would require significant commitments in the case of Bangladesh, however, since binding overhang is probably more severe in Bangladesh than in any other country in the region. A similar case can be made for Viet Nam and the Russian Federation, which, as newly acceded members (assumed in the case of the latter), do not make any further commitments under this scenario. Substantial reductions in developing country tariffs also create new potential pathways to positive terms of trade shifts (such as through expansion of South-South trade in agricultural products).

To explore this possibility further, we consider the regional allocation of gains from reform under the comprehensive agricultural reform scenario. Under comprehensive reform, all developing economies in the region experience positive welfare gains except Bangladesh and the Philippines, where the results remain negative (but small). The results for several countries stand out. Notably, Malaysia, the Republic of Korea, Sri Lanka and Thailand benefit substantially in proportional terms under this scenario. India also gains substantially in dollar terms, and is a classic case of large allocative efficiency gains being able to outweigh terms of trade losses, much like in the cases of the Republic of Korea and Japan. In Bangladesh and the Philippines, the efficiency gains are positive, but not enough to outweigh terms of trade loss. Finally, we consider Malaysia, a net loser under Doha, but a substantial gainer under comprehensive reform (indeed, the largest gainer in proportional terms). Interestingly, much of the gain is from terms of trade effects. This unanticipated result suggests that there is scope for market access gains with agricultural reform for Malaysia also, but that the current modalities are not addressing the areas that would benefit the country (suggesting that reform

does not go far enough in some niche products in which Malaysia has a strong comparative advantage, and that the opening of Southern as well as Northern markets is particularly crucial for that country).

Overall, the results lead us to two major conclusions. First, the current reform scenario in agriculture is unlikely to generate significant positive (or negative) impacts on most economies in the Asia-Pacific region; the current proposed modalities simply do not go very far in terms of cutting into binding overhang. To the extent that reform does occur, the concerns of developing economies and LDCs over adverse terms of trade movements (both preference erosion and increased food import prices fall into this category) do appear to be justified for many developing economies in the region, although the effects are not large. Moreover, expansion of preferential access for LDCs may not have the potential to ameliorate this effect, as even with zero tariffs on all agricultural goods offered by developed economies, preference erosion effects lead to terms of trade losses for an economy like Bangladesh. The second conclusion relates to the impact of expanded reform and special and differential treatment. Tariffs in many developing economies are quite high, suggesting that substantial gains from increased efficiency are possible—gains that could outweigh the small negative effects of reform in some countries. A more comprehensive reform agenda, embracing reform in both developed and developing economies, would result in much larger aggregate gains and a much larger pool of winners.

Poverty

We now turn to the possible effect of the Doha and comprehensive reform scenarios on poverty. Table 4 reviews the poverty statistics in the region. These have been drawn from the World Bank (2007), and we have selected the data year that is closest to our base year for each economy. The mean income figures are in United States dollars, adjusted for purchasing power, and are per month. Several measures are provided. The most basic measure of poverty is the headcount ratio: the proportion of the population that falls below a defined poverty line. Commonly used criteria are the international $1/day standard and the $2/day standard, with the higher standard more widely applied to countries with higher average incomes. The headcount is the actual number of people in that category (in millions).[14] The total number in extreme poverty in the selected economies circa 2002 was approximately 620 million by the $1/day criterion and 1.7 billion by the $2/day criterion, with significant variation across economies and, in some cases,

[14] See Chen and Ravallion (2004) for a more in-depth discussion of poverty measures and trends in global poverty.

Table 4. Indicators of poverty/income inequality for developing economies in the Asia-Pacific region circa 2002

Country/region	Data year	Mean income ($/month)[a]	Gini (percentage)	$1/day poverty line				$2/day poverty line			
				Headcount ratio (percentage)	Headcount (millions)	Poverty gap (percentage)	Squared poverty gap (percentage)	Headcount ratio (percentage)	Headcount (millions)	Poverty gap (percentage)	Squared poverty gap
Bangladesh	2000	46.9	33.4	41.3	54.1	10.4	3.5	84.2	110.4	39.1	21.3
China (rural)	2002	68.7	38.0	22.4	175.0	5.0	1.5	65.1	507.5	25.3	12.5
China (urban)	2002	219.3	33.5	0.3	1.6	0.1	0.1	3.4	16.8	0.7	0.3
India (rural)	2000	42.3	28.1	41.8	302.7	10.2	3.4	88.4	640.5	40.8	21.9
India (urban)	2000	70.5	35.0	19.3	52.9	3.9	1.1	60.5	166.2	22.5	10.6
Indonesia	2002	81.3	34.3	7.8	16.5	1.0	0.2	52.9	112.0	15.9	6.2
Malaysia	1997	321.7	49.2	0.1	0.0	0.0	0.0	8.8	1.9	1.9	0.6
Mexico	2002	204.7	49.7	4.3	4.3	0.9	0.3	21.2	21.2	6.7	2.9
Philippines	2000	110.9	46.1	13.5	10.4	2.4	0.6	44.9	34.4	16.3	7.6
Russian Federation	2001	170.8	39.6	1.8	2.6	0.4	0.1	16.8	24.3	4.4	1.7
Sri Lanka	2002	105.4	40.2	5.8	1.1	0.7	0.1	41.5	7.9	12.1	4.6
Thailand	2002	145.2	42.0	0.9	0.6	0.0	0.0	25.8	16.2	6.2	2.0
Viet Nam	2002	114.8	37.6	1.8	1.4	0.1	0.0	33.2	26.7	8.3	2.7

Source: World Bank (2007). *Povcal* (Washington, D.C.)

[a] Adjusted for purchasing power

across regions within economies (the headcount ratios are split by rural and urban for two major economies, China and India, with substantially higher levels of poverty in the rural regions in both cases).[15] Poverty is most severe in Bangladesh, rural China and India, and Indonesia.

Two other measures, both of which attempt to address the issue of poverty depth, are provided in table 4. The poverty gap measure is the mean distance below the poverty line as a proportion of the poverty line. The squared poverty gap weights individual poverty gaps by the gaps themselves, and provides a measure of inequality among the poor. The areas with the greatest poverty depth are Bangladesh and rural India. Finally, the Gini coefficient is a common measure of overall income inequality, with the greatest levels of inequality in Malaysia, the Philippines, Sri Lanka and Thailand.

How might these patterns change with agricultural reform? A single representative household model like GTAP does not generate any direct measures of poverty (hence the use of sub-models in the country studies reviewed above). However, it is possible to gain some insights into the effects that trade reform may have on the poor through aggregate indices.

Anderson, Martin and van der Mensbrugghe (2006) argue that the incomes of the poor are dominated by returns to the factor of production that they own in the greatest abundance: their own (unskilled) labour. The most relevant consumption categories for poorer households are primary food products, and textiles. Hence, we can construct an index that measures the proportional change in the wages of unskilled workers, deflated by changes in the price index for those critical commodities. We might term this index the "real wage" of the poor. We can convert the index numbers into poverty measures using consumption to poverty elasticities.[16] Measures of the latter were obtained from World Bank (2007) estimates, evaluated using both a $1/day criterion and a $2/day criterion.

The use of this approach implies several assumptions, including distribution neutrality of the proposed income change within the target group. Also, as Anderson, Martin and van der Mensbrugghe (2006) note, it is implicitly assumed

[15] The 1.7 billion figure is of course likely to be a significant underestimate of poverty in the region because our data only tracks a subset of the economies. Also, the figure for Viet Nam should be regarded with some caution as real exchange rate data for that economy is not regarded as reliable.

[16] It is also possible to base the calculations on average changes in real incomes, assuming complete distribution neutrality. Anderson, Martin and van der Mensbrugghe (2006) argue that linking key model variables to the possible change in the average per capita consumption of the poor, as this index attempts to do, better captures from model results some of the distributional aspects of the changes in real income and not simply the average gain.

that the change in unskilled wages is fully passed through to households and that tariff revenues are replaced only by skilled workers and high-income households. Anderson, Martin and van der Mensbrugghe (2006) argue that this is a realistic assumption in many developing countries. While the calculations are clearly rough estimates, they do give us some quantitative indications on the likely patterns of poverty change.

The results are presented in table 5. Under the $1/day criterion, we estimate a reduction in poverty in the region by 7 million under the Doha reform scenario, rising to 17 million by the $2/day criterion. Overall then, we estimate that agricultural trade reform under Doha would have a beneficial if generally mild effect on poverty in the region. Once again, the distribution is not even, however. The majority of the positive impact is in rural China, while rural India experiences a rise in the number of people below the poverty line.[17]

Here we note two points of interest. First, an aggregate welfare gain does not necessarily correspond to a reduction in poverty (China is estimated to lose overall under Doha, although by a negligible magnitude, while India is estimated to gain). This is because the poverty index we are using here, following Anderson, Martin and van der Mensbrugghe (2006), uses the real unskilled wage as the base, and this can move in the opposite direction to overall welfare. Second, in some countries (such as India) poverty rises while aggregate income rises. Since aggregate welfare levels are higher under the reform scenario (see table 3), it must be feasible to arrange a transfer under which poverty levels in fact decline, if the political will to do so exists. In other words, these calculations are based on an implicit assumption of business as usual in income distribution policy, but ultimately that is a domestic policy choice.

The results for the comprehensive reform scenario indicate a much greater impact on poverty. Under the $1/day criterion, we estimate a reduction in poverty in the region by 51 million under the Doha reform scenario, rising to 65 million by the $2/day criterion. Again, the distribution is uneven, with the majority of poverty reduction in rural China, but the results indicate that in the long run poverty would fall to some degree under comprehensive agricultural reform in all of the economies for which we are able to undertake the analysis except Sri Lanka. Again, we might note that since Sri Lanka gains overall in this scenario, it should be possible for poverty to be reduced there also, if the political will exists.

[17] Our headcount estimates are somewhat larger than those in Anderson, Martin and van der Mensbrugghe (2006). This probably reflects the fact that the earlier study was measured relative to a projected 2015 baseline, under which growth has already reduced poverty significantly below levels circa 2001 (i.e., the baseline is different).

Table 5. Estimated changes in indicators of poverty under agricultural trade reform

Country/region	Doha scenario		Comprehensive scenario	
	Headcount ratio (percentage change)	Headcount (change in millions)	Headcount ratio (percentage change)	Headcount (change in millions)
$1/day poverty line				
Bangladesh	0.6	0.3	-4.5	-2.4
China (rural)	-6.6	-11.5	-15.6	-27.3
China (urban)	-7.1	-0.1	-16.9	-0.3
India (rural)	2.0	5.9	-3.3	-10.0
India (urban)	2.4	1.3	-4.0	-2.1
Indonesia	-7.3	-1.2	-22.8	-3.8
Malaysia	-1.8	0.0	-20.0	0.0
Mexico	-2.8	-0.1	-7.6	-0.3
Philippines	-8.1	-0.8	-23.4	-2.4
Russian Federation	0.3	0.0	-21.0	-0.5
Sri Lanka	1.2	0.0	7.7	0.1
Thailand	-95.0	-0.5	-100.0	-0.6
Viet Nam	-12.3	-0.2	-100.0	-1.4
$2/day poverty line				
Bangladesh	0.1	0.1	-1.1	-1.2
China (Rural)	-2.6	-13.2	-6.2	-31.3
China (Urban)	-11.4	-1.9	-27.1	-4.5
India (Rural)	0.3	2.2	-0.6	-3.7
India (Urban)	1.0	1.6	-1.6	-2.7
Indonesia	-1.9	-2.1	-5.8	-6.5
Malaysia	-0.4	0.0	-4.6	-0.1
Mexico	-1.4	-0.3	-3.7	-0.8
Philippines	-3.3	-1.1	-9.5	-3.3
Russian Federation	0.1	0.0	-10.5	-2.6
Sri Lanka	0.3	0.0	2.0	0.2
Thailand	-12.0	-1.9	-27.9	-4.5
Viet Nam	-1.9	-0.5	-16.9	-4.5

Source: Global Trade Analysis Project simulations and calculations from World Bank (2007). Povcal (Washington, D.C.)

It is worth considering whether these aggregate results match with the results generated by the more detailed models, as an indicator of consistency and the extent to which these kinds of estimates are useful. Because the detailed results for India (Gilbert 2007) were generated using a consistent data set and experimental design, they provide the most direct comparison. The results of the detailed model indicated positive aggregate welfare gains in all scenarios, with the largest gains in the long run with comprehensive reform. This is consistent with the GTAP results. At the household level, the results suggested that under Doha there would be a decline in the incomes of the poorest groups, which were a subset of rural households. This is consistent with the marked increase in rural poverty that the aggregate method predicts. Moreover, in the long run with comprehensive reform, the detailed model predicted an increase in the incomes of the poorest groups, and the GTAP model indicated a decline in poverty levels under the same scenario. When calculating poverty changes from the household data, the Gilbert (2007) results were more moderate than those estimated here, both in terms of the rise under Doha and the fall under comprehensive.

All of the other available studies consider the broad Doha agenda, but nonetheless the results are generally consistent. The results of Annabi and others (2006) for Bangladesh match the somewhat bleak scenario that our analysis paints for that economy (that is, falls in aggregate welfare and rises in poverty under all Doha scenarios). The results for the Philippines by Cororaton, Cockburn and Corong (2006) also match, and in particular we find that the comprehensive scenario has a stronger impact on Philippine poverty levels, as suggested by Cororaton, Cockburn and Corong (2008). The results for Indonesia are consistent with Robilliard and Robinson (2006) in terms of sign but not magnitude, with our results indicating much larger poverty impacts. This is likely because of a difference in definition. Robilliard and Robinson (2006) use an official Indonesian poverty line, which is significantly lower than the $2/day criterion, resulting in less scope for poverty reduction. Similarly, the results of Zhai and Hertel (2006) for China also indicate poverty reduction, with the majority occurring in the rural areas. This is consistent with our results, but the magnitude we estimate is larger, in part reflecting lower initial poverty estimates in the Zhai and Hertel (2006) base. Overall, there is a broad consistency between the results, suggesting that the aggregate approach adopted in Anderson, Martin and van der Mensbrugghe (2006) and here at the least provides a useful guideline.[18]

[18] Although our results suggest a decline in poverty in Viet Nam, a comparison with Linh, Burton and Vanzetti (2008) is not feasible given their specific focus on farm households.

Adjustment

A comparative-static-type model does not generate information on the adjustment path to the new equilibrium. Nonetheless, adjustment costs associated with trade reform may be an important, if temporary, poverty component, especially if they tend to be borne by groups known to be at or close to the poverty line. Understanding the likely magnitude of adjustments required may therefore be useful in designing policies to alleviate those costs.

Existing studies have not attempted to address the adjustment cost issue. One way to gain some indirect insights is by considering indices of the magnitude of economic changes within the system. Given our interest in how agricultural trade reforms impact the poor, we consider adjustment of unskilled labour in detail. It is important to note that the indices we consider do not measure the magnitude of the adjustment costs themselves, but rather tell us which economies are likely to face relatively high adjustment costs, and by whom those costs are likely to be borne.

We calculate two types of index. In the first, labelled "shift", we take the employment share weighted average of the absolute values of the proportional changes in sectoral level employment of unskilled labour. This provides a measure of the extent to which unskilled labour is forced to change the sector in which it is employed as a consequence of the trade reform. The index is greater than zero, with numbers close to zero indicating less adjustment, and larger numbers indicating greater adjustment. We calculate the index both for the economies overall and for the agricultural subset.

The second index we have labelled "impact". This is the production share weighted average of only the negative employment shifts. The rationale for this index is as follows. Suppose that an economy is rocked by some price shock. The consequence will ultimately be a reallocation of resources, including unskilled labour, as some industries contract and others expand. The worst case adjustment scenario is that industries adversely affected by the shock immediately reduce their employment (an instantaneous impact), while those positively affected increase their employment only slowly at some point in the future. Therefore, the impact measure can be interpreted as the upper bound estimate of the fall in the rate of employment of unskilled labour, prior to any uptake in new sectors. Again, we calculate this statistic for the economy overall, and for unskilled labour in agricultural sectors only.

The results of our analysis are presented in table 6. Under the Doha scenario, barring New Zealand, the results are quite moderate overall, as we might

expect given the small changes in the aggregate economic variables, with the largest adjustments and largest potential negative impacts on unskilled labour employment levels in the Philippines and Thailand. The worst-case changes are all less than 1 per cent.[19]

Table 6. Estimated employment adjustment indices under agricultural trade reform

Country/area	Doha scenario				Comprehensive scenario			
	Overall		Agriculture		Overall		Agriculture	
	Shift	Impact	Shift	Impact	Shift	Impact	Shift	Impact
Australia	1.2	-0.6	7.7	-1.5	3.4	-1.7	26.8	-8.9
New Zealand	3.0	-1.5	9.1	-1.6	4.4	-2.2	13.5	-2.3
China	0.6	-0.3	1.2	0.0	1.2	-0.6	2.5	0.0
Hong Kong, China	0.1	0.0	1.2	-0.3	0.1	0.0	1.9	-0.8
Japan	0.2	-0.1	2.5	-0.4	1.0	-0.5	16.5	-13.2
Republic of Korea	0.5	-0.3	4.8	-1.2	1.8	-0.9	16.8	-7.9
Indonesia	0.5	-0.2	0.8	0.0	2.1	-1.0	4.5	-0.7
Malaysia	0.1	-0.1	1.7	-0.9	4.1	-2.0	52.1	-13.9
Philippines	1.4	-0.7	1.5	0.0	3.1	-1.6	4.8	-1.4
Singapore	0.2	-0.1	6.9	-2.3	0.3	-0.2	8.7	-2.9
Thailand	1.0	-0.5	2.7	-0.6	4.5	-2.2	15.3	-5.5
Viet Nam	0.4	-0.2	1.2	-0.1	2.4	-1.2	10.0	-4.1
Bangladesh	0.1	-0.1	0.4	0.0	1.2	-0.6	3.6	-1.9
India	0.2	-0.1	0.4	-0.3	1.5	-0.7	2.6	-2.3
Sri Lanka	0.1	0.0	0.3	-0.1	1.9	-1.0	4.0	-0.3
Russian Federation	0.4	-0.2	1.7	-0.1	0.6	-0.3	3.9	-2.5
Canada	0.2	-0.1	2.3	-0.7	0.3	-0.2	4.6	-3.4
Mexico	0.3	-0.2	1.6	-0.7	0.8	-0.4	4.2	-2.2
United States of America	0.1	0.0	1.1	-0.9	0.1	-0.1	1.8	-1.8
European Union	0.2	-0.1	2.0	-1.7	0.4	-0.2	4.1	-2.7
South & Central America	0.4	-0.2	1.8	-0.3	0.6	-0.3	2.7	-0.5
Rest of world	0.3	-0.2	0.9	0.0	0.7	-0.4	2.4	-0.5

Source: Global Trade Analysis Project simulations by author.

Notes: Shift = Weighted average percentage change in employment by sector
Impact = Instantaneous fall in employment rate

[19] Moderate changes are also observed in Australia and New Zealand, largely reflecting the pulling of resources into agriculture. On the other hand, in the Republic of Korea there are large adjustments reflecting the pushing of resources out of agriculture. The percentage change for Singapore is large also, but its economic significance must be interpreted in the light of the overall significance of agricultural production for Singapore, which is less than 1 per cent of GDP. Similarly, agricultural output as a proportion of GDP is low in Japan and the Republic of Korea. In any case, we would suspect that developed economies are better equipped to deal with transitional problems.

When we consider just agricultural labour, the results are more significant. This result suggests that the burden of adjustment falls unevenly, with unskilled labour employed in agriculture and the food processing industries generally having to shift activities at rates greater than the average shift, and having a greater probability of being temporarily unemployed in the adjustment phase. Hence, for example, unskilled agricultural labour in Malaysia must adjust at approximately 17 times the rate of unskilled labour overall, and is nine times more likely to face temporary unemployment (at the upper bound).

The comprehensive agricultural reform scenario would, not surprisingly, entail much greater adjustment. Our results indicate that the most adversely affected economies would be Malaysia, the Philippines, the Republic of Korea, Thailand and Viet Nam, where temporary falls in employment of unskilled labour in the region of 1 to 2 per cent are possible, with a disproportionate burden borne by agricultural workers (especially in Malaysia).

In summary, adjustment costs are temporary, and are part of the price of increased efficiency in the long term. CGE modelling does not address this issue directly. Nonetheless, our simulation results indirectly show that moderate sectoral adjustment is likely in agriculture throughout the region under Doha, and that the costs of adjustment are likely to be borne in large part by unskilled agricultural labour. This effect may contribute adversely to poverty during the adjustment phase if other policies are not put in place to address transition problems.

VI. CONCLUDING COMMENTS

In this paper we have considered the potential implications of agricultural trade reform under Doha on overall welfare and poverty for economies in the Asia-Pacific region. The approach has been to survey the results of the limited number of detailed country studies, and construct new results based on simulations using the GTAP model. The latter differ from existing work by concentrating on the agricultural reform in the Asia-Pacific region, drawing on the latest proposed modalities and tariff data, making use of the latest poverty elasticity estimates, and by addressing the issue of adjustment costs.

The results suggest that the level of agricultural reform currently being considered under Doha does not make sufficient cuts into the binding overhang to generate large welfare benefits. The very moderate cuts currently being proposed will likely have only a limited impact on developing economies. We do find some evidence to suggest that preference erosion may lower welfare in some economies, as may rising world prices, but again at very low levels given the limited degree of

actual liberalization proposed. In aggregate welfare terms, many developing economies would do better by engaging more fully in the liberalization process, since own-reform gains are under developing country control and likely to be more substantial than any conceivable benefit from tariff preferences. Most developing countries in the region would be winners, in aggregate welfare terms, under comprehensive agricultural trade reforms.

In terms of poverty, our aggregate results suggest that agricultural trade reform currently proposed under Doha may indeed hit the poor disproportionately in some countries in the region, by lowering unskilled wages and/or raising the prices of basic foodstuffs. However, the aggregate poverty levels decline by moderate amounts. This result is consistent with the results of the detailed studies available. The effect of comprehensive reform is a much more robust and broad-based decline in poverty levels in the region. The temporary burden of adjustment, however, does tend to be borne inequitably by the owners of unskilled labour, in particular those employed in agricultural activities, and Governments in the region will need to carefully consider complementary adjustment policies in conjunction with trade reform.

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ANNEX

LATEST PROPOSED DOHA MODALITIES*

Market access

- Members shall reduce their bound duties following a tiered formula requiring reductions of 48 to 73 per cent for developed countries depending on the initial bound levels. Commitments for developing economies have higher bands and lower required reductions (two thirds of developed economy levels). The least developed members and very recently acceded members (including Viet Nam) are not required to undertake any reductions beyond those already committed. "Small and vulnerable" economies, defined as those with an average share of world trade of 0.16 per cent or less, an average share of non-agricultural trade of 0.1 per cent or less and a share of world agricultural trade of no more than 0.4 per cent, are entitled to moderate the required cuts by a further 10 percentage points.

- Developing country members may lower their commitments proportionately across bands if their average reductions under the formula exceed 36 to 40 per cent. Small and vulnerable members may do the same if their average reductions under the formula exceed 24 per cent.

- Developed economies may designate 4 to 6 per cent of dutiable lines as sensitive, with developing economies entitled to 5 to 8 per cent. These require reductions at two thirds of the rate required under the tiered-formula.

- Developed country members commit to duty- and quota-free market access for all products originating in the least developed countries by 2008 or the start of the implementation period.

* See World Trade Organization (2007). "Draft possible modalities on agriculture", paper presented at the special session of the Committee on Agriculture on 17 July.

Domestic support

- Reduction of total aggregate market support (AMS) in the range of 45 to 70 per cent, in accordance with a tiered formula.[a] Developed countries with a level of total AMS of at least 40 per cent of the total value of agricultural production shall reduce by a further 10 per cent if their total AMS is in the second tier, and by 5 per cent if they are in the third tier.
- Reduction in the base level of overall trade-distorting domestic support in the range of 50 to 85 per cent in accordance with a tiered formula.[b] Developed country members in the second tier with overall trade-distorting domestic support of at least 40 per cent of the total value of agricultural production shall reduce by a further 4 to 6 per cent.
- Developing economy member reductions are two thirds of those of developed economies, while small, low-income, recently acceded members are not required to undertake a reduction in total AMS.
- *De minimis* levels (the lower bound of support levels that must be reduced) are cut by 50 to 60 per cent from those set out under the Uruguay Round Agreement on Agriculture (that is, 5 per cent for developed economies and 10 per cent for developing economies).

Export competition

The commitment on export competition is elimination of export subsidies by 2013 for developed economies, and an as yet unspecified reduction by developing economies.

[a] Aggregate market support (AMS) is a monetary measure of the total sectoral support, including both direct payments and the revenue transfers from consumers as a consequence of price distorting policies.

[b] Overall trade-distorting domestic support is defined as total AMS plus 10 per cent of the value of production in the base period, 1995-2000, plus the higher of the existing average blue box payments (certain production limiting programs) or 5 per cent of the average total value of production in the base period.

AIR POLLUTION AND INCOME DISTRIBUTION IN INDIA

*Kakali Mukhopadhyay**

Concern over the environmental effects of fossil fuels in India has been growing as domestic consumption levels increase. Along with industry, households are major consumers of commercial energy and, consequently, major contributors to the total energy use in India. Emission levels in the country are gradually increasing.

The present study estimates emissions related to fossil fuel combustion in India and also identifies the factors responsible for changes in those emissions during the 1980s and 1990s. Results show that the factor relating to changes in final demand, which reflect increased economic growth, had the greatest influence on emission levels.

The study disaggregates households into three income groups, examining the contribution each makes to fossil-fuel-based pollution in India with respect to the various factors identified. Analysis indicates that higher- and middle-income groups generated more pollution due to excessive and inefficient consumption of commercial energy. The paper concludes with a discussion of policy implications.

I. INTRODUCTION

Industrialization and urbanization have resulted in a profound deterioration of the air quality in India. While the country's gross domestic product has increased 2.5 times over the past two decades, vehicular pollution has increased eight times, and pollution from industries has quadrupled.

Environmental problems range from the hazards of ever-increasing levels of pollutants to ecosystem degradation. Global warming is not the only problem

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associated with major energy sources and usage patterns; other related environmental issues include air pollution, acid precipitation, ozone depletion, forest destruction and the emission of radioactive substances. Pollutants such as sulphur dioxide (SO_2), mono-nitrogen oxides (NO_X) and carbon dioxide (CO_2) are produced mainly through the combustion of fossil fuels, such as coal, crude oil and natural gas. Increasing consumption levels add to the growing concerns about the environmental effects of these fuels; in recent years, the effect of air pollution on health has been a major focus of attention.

Although fossil fuel use in developing countries is still half that of developed countries, it is expected to increase 120 per cent by the year 2010. It has been estimated that, if control measures are not implemented, by the year 2020 more than 6.34 million deaths will occur in developing countries due to ambient concentrations of particulate air pollution (Romieu and Hernandez 1999).

In a survey conducted by the Central Pollution Control Board of India, 23 Indian cities were identified as critically polluted (India 2000a). The survey reported that 12 major metropolitan cities in India produced 352 tons of nitrogen oxides, 1,916 tons of carbon monoxides from vehicular emissions and 672 tons of hydrocarbons per year. The levels of CO_2, SO_2 and NO_X in the ambient air of India are above the limit established as safe in the World Health Organization annual mean guidelines for air quality standards. Those limits are set at 90 micrograms per cubic meter for total suspended particulates and 50 micrograms per cubic meter each for sulphur dioxide and nitrogen dioxide (World Bank 1999). But the levels of SO_2 and NO_x in urban air pollution from major cities in India are growing rapidly. Needless to say, at these levels, such pollution is likely to have a serious impact on health. According to the United States of America Energy Information Agency, the World Health Organization named the capital city of New Delhi as one of the 10 most polluted cities in the world in 1998 (see Corrosion Doctors website, http://corrosion-doctors.org/AtmCorros/mapIndia.htm).

People who live in poverty are exposed to the worst environmental and health risks. Somewhere between 25 and 33 per cent of the global burden of diseases can be attributed to environmental factors (Kjellén 2001). In India, about one third of the population is below the poverty line (India 2001c) and, consequently, among those at a high risk of being affected by environmental hazards.

Because development requires energy use, increased development will inevitably affect health. The present study examines the above issues in the context of the need to control and regulate the emission of pollutants.

Households are major consumers of energy and, consequently, major contributors to the total energy use of the nation. At present, households in India account for about 40 per cent of the use of total direct commercial and non-commercial indigenous energy (Pachauri and Spreng 2002). If one takes into account the indirect or embodied energy in all goods and services purchased by households, then about 70 per cent of the total energy use of the economy can be related to the household sector; the remaining 30 per cent comprises the energy requirements of Government consumption, investments and net imports (Pachauri and Spreng 2002). The distribution of energy consumption with regard to the population shows that over 60 per cent of households have a per capita total household energy requirement of less than 0.5 kilowatts per year. In addition to the wide disparities among households in the quantities of energy used, there are large variations in the types of energy used and the patterns of consumption.

During the past few decades, India has experienced many changes in its energy consumption patterns, both in quantitative and qualitative terms (Centre for Monitoring Indian Economy 2001). This is due to a natural increase based on population growth, as well as to the increase in economic activity and development. As mentioned, the household sector is one of the largest users of energy in India. The pattern of household energy consumption represents the status of welfare and the stage of economic development of the country. As the economy develops, more and cleaner energy is consumed. Moreover, household energy consumption patterns are likely to vary according to income distribution and its change over time. Household energy consumption is expected to increase along with economic growth and rises in per capita income. The projected increases in household energy consumption are expected to result from changes in lifestyles (Pachauri 2004). In this connection, a study is needed to estimate the air pollution generated from fossil fuel combustion, disaggregated by income group in India.

The core objective of the present paper is to estimate what the industrial emissions of CO_2, SO_2 and NO_X were in India during the period 1983/84 to 1998/99. The sources of change in industrial CO_2, SO_2 and NO_X emissions are investigated through input-output structural decomposition analysis (SDA)[1] for that period. A breakdown of the emissions contributed by different income groups during the study period is also calculated.

[1] Structural decomposition analysis (SDA) is a technique for studying period-to-period changes. It has become a major tool for disentangling the growth in some variables over time, separating the changes in the variable into constituent parts. SDA is used to distinguish major sources of change in the structure of the economy, broadly defined by means of a set of comparative static changes in key parameters of an input-output table.

Section II briefly reviews the literature on air pollution and health at the national and international levels. In section III, a model is formulated to estimate the industrial emissions of CO_2, SO_2 and NO_X in India, the changes in emission levels and the major factors behind the changes. The data sources and processing methodology used are presented in section IV. In section V, detailed empirical findings on changes in emission levels are analysed with respect to the factors responsible for changes in energy consumption during the period 1983/84 to 1998/99. The contribution of emissions made by different income groups is also discussed. Policy implications are discussed in the conclusion.

II. LITERATURE REVIEW

The literature on the estimation of emissions, particularly in a country framework, is extensive. A brief discussion on developed and developing countries, including India, follows.

Several researchers have estimated the direct and indirect energy requirements of households in developed countries, such as New Zealand (Peet, Carter and Baines 1985), Germany (Weber and Fahl 1993), the Netherlands (Vringer and Blok 1995, Wilting 1996) and Australia (Lenzen 1998).

In one paper indicative of this literature, Wier and others (2001) evaluate the correlation between the consumption patterns of various household types and their CO_2 requirements in Denmark, using an integrated modelling framework, and relate differences in household types to differences in both private consumption and CO_2 emissions. They identify household characteristics that have a significant influence on CO_2 emissions. Comparing their results with those of other studies, Wier and others state that national variations in climate and population densities can affect the levels to which households contribute to CO_2 emissions. Finally, national differences in income and expenditure elasticities of both energy and CO_2 are found to be due to the disparity in CO_2 intensities among commodities as well as to the assumptions regarding foreign technology that were included in the model. In another paper, Munksgaard, Pedersen and Wier (2000) trace the environmental impacts of consumption in Denmark. They include impacts originating from production layers of infinite order (capturing the entire economy). The authors present measures of CO_2 emissions at different spatial levels: the nation, city and household. Furthermore, they introduce the concept of environmental efficiency by combining input-output modelling and data envelopment analysis. The policy relevance of the different measures is also discussed.

Studies on developing countries, however, are much fewer in number. A World Resources Institute study (1998) shows that air pollution levels in China are among the world's highest. This is due to the country's growing consumption of coal. Coal burning, a primary source of the high SO_2 emissions in China, accounts for more than three quarters of the country's commercial energy needs, compared with 17 per cent in Japan and a world average of 27 per cent. The study finds that the energy and industrial sectors are the major contributors to urban air pollution in China. Emissions from the transport sector are also increasing.

Jiang and O'Neill (2006) study the impacts of economic growth and demographic changes on residential energy consumption and the environmental consequences of such consumption in China. Using the Rural and Urban Socio-economic Household Survey data sets for China in the 1990s as well as historical socio-economic, demographic and macrodata on energy use, the authors analyse the relative importance of changes in residential energy use to the general trends of overall energy consumption, and study the relationship between population, income and energy consumption and the latter's consequent emission of pollution. Through a statistical analysis of Chinese rural and urban household energy consumption, Jiang and O'Neill stress the importance of urbanization in the energy transition from biomass to modern fuel. Combining population and household projection results, the authors simulate the impacts of household compositional changes and urbanization on future residential energy consumption under different socio-economic and demographic scenarios.

Some studies focus on the transport sector (which is also a part of household energy consumption) as a major polluter. Others analyse indoor energy consumption, and show that it is responsible for the bulk of household emissions. Most of the studies focus on air pollution and its related health impacts, exploring sources and different sectors, especially transport and industry. Very few studies attempt to estimate the levels of pollution generated by different income groups.

Chaudhuri and Pfaff (2003) estimate the fuel-choice decisions of households in a poor developing economy, in particular the choice between dirtier traditional fuels (wood, dung and other biomass) and cleaner modern fuels, such as kerosene and natural gas. These choices directly influence the levels of indoor air quality enjoyed by the households. Results provide empirical support for a household production framework in which non-monotonic environmental Engel curves can arise quite naturally. Furthermore, estimates yield an inverted-U relationship between indoor air pollution and income, mirroring the environmental Kuznets curves.

Researchers at the Indira Gandhi Institute of Developmental Research carried out in-depth studies using input-output analysis and aggregated household

expenditure survey data to calculate the CO_2 emissions from energy consumption for different groups of households in India for the year 1989/90 (Murthy, Panda and Parikh 1997a and 1997b and Parikh, Panda and Murthy 1997).

Pachauri (2004) analyses the variation in the pattern and quantum of both direct and indirect household energy requirements, using microlevel household survey data from India for the year 1993/94. Results reveal that household socio-economic, demographic, geographic, family and dwelling attributes influence the total household energy requirements. It shows that total household expenditure or income level is the most important explanatory variable causing variation in energy requirements across households. In addition, the size of the household dwelling and the age of the head of the household are related to higher household energy requirements.

Reddy (2004) analyses the dynamics of energy end-use in the household sector in India. It is observed that large variations in the use of energy exist across different sections of households, such as urban/rural and low/high-income groups. The paper further explores the energy-poverty nexus, impacts of household energy use on livelihood and gender issues. The positive effects of the innovation of energy efficiency and specific policies to achieve the potential for energy efficiency are also discussed.

Gupta, Keswani and Malhotra (1997) estimate greenhouse gas emissions for three reference years: 1980/81, 1985/86 and 1987/88, using a simple spreadsheet model. Bose (1998) has constructed a transport simulation model to evaluate automotive energy use and control of emissions for four Indian metropolises (Bangalore, Mumbai, Calcutta and Delhi) during the period 1990-2011. Sikdar and Mondal (1999) suggest that air quality management aimed at reducing stationary- and mobile-source emissions will help mitigate air pollution and improve quality of life. Chitkara (1996) explains the factors affecting air pollution, emission discharges and their sources (vehicular, domestic, industrial and energy use related). The Energy and Resources Institute (1997) has made a few estimates of the effects of SO_2, particulate matter, carbon monoxide and carboxyhaemoglobin at various concentrations (parts per million) and exposures (time) and then estimated the corresponding health effects.

In one study, Sinha and Bandyopadhyay (1998) attempt to capture the metallic constituents of aerosol present in the biosphere which have been identified as potential health hazards. They conclude that controls on emissions from industrial operations would help keep the metallic concentration within limits in the ambient air. Mukhopadhyay and Forssell (2005) estimate air pollution from fossil fuel combustion in India. The input-output SDA approach is used to find out the

sources of changes in emissions. A link between the emission of pollutants and their impact on human health is analysed. The authors find that pollution and health impacts have a close linear relationship in India.

The studies above focus on household energy consumption from a developing country perspective. But a discussion of the generation of pollution in India, particularly when disaggregated by income class and economic factor, is rare in the literature; these aspects are examined in the present paper.

III. MODEL FORMULATION

In the present study, a model is developed based on the input-output SDA for the estimation of pollutant emissions (CO_2, SO_2 and NO_x) and factors responsible for changes in emissions. The model is further extended to incorporate different income groups.

Model 1 is founded on the basic concepts of the input-output framework of Leontief (1951). Mathematically, the structure of the input-output model can be expressed as

$$X = A + Y. \quad (1)$$

The solution of (1) gives

$$X = (I - A)^{-1} Y, \quad (2)$$

where X is a vector of output, Y is a vector of final demand and $(I - A)^{-1}$ is the matrix of total input requirements. For an energy input-output model, the monetary flows in the energy rows in equation (2) are replaced with physical flows of energy to construct an accounting identity which conforms to the energy balance condition (Miller & Blair 1985). We apply a hybrid method based on Miller and Blair (1985); it always conforms with energy conservation conditions.

On the basis of the estimated parameters we calculate the direct as well as the total (direct and indirect) CO_2, SO_2 and NO_x emission coefficients (see annex). An emission model is used to calculate the CO_2, SO_2 and NO_x emissions attributable to fossil fuel combustion in production activities in India (see annex). Then, an SDA is developed to estimate the changes in emissions in each period as well as to capture the factors responsible for such changes. The factors identified are: (a) changes in emission intensity, (b) changes in technology and (c) changes in the final demand of various industries (see annex).

In Model 2, Model 1 has been extended to calculate the contribution to emission changes by income group.[2] Model 2 also estimates the degree to which emissions among each income group are influenced by selected factors (see annex).

IV. DATA SOURCES AND PROCESSING

To implement the model and to conduct the SDA of energy consumption changes among different income groups, we require input-output data, price indices, energy-flow and emissions data and the consumption expenditure of various commodities for different expenditure classes (India 1984, 1991, 1995 and 2001b).

Data from input-output tables for the Indian economy for the years 1983/84, 1989/90, 1993/94 and 1998/99, prepared by Central Statistical Office (India 1990, 1997a, 2000b, 2005),[3] are used. Input-output tables are commodity-by-commodity tables consisting of 115 by 115 sectors. Those have been aggregated to 47 sectors on the basis of the nature of the commodities and energy intensiveness.

We use 1993/94 as a base year and adjust the 1989/90, 1993/94 and 1998/99 tables (India 1991, 1995 and 2001) to 1993/94 prices using suitable price indices available from the National Accounts Statistics.

We convert the monetary units of energy sectors into physical units from the energy data published by the Centre for Monitoring Indian Economy (1991, 1995, 1999 and 2003). Three energy sectors—coal, crude petroleum and natural gas, and electricity—have been converted into one common unit: million tons oil equivalent. Estimates of CO_2, SO_2 and NO_x emissions are made on the basis of the Intergovernmental Panel on Climate Change guideline.

Data from National Sample Survey rounds 38 (1983/84), 45 (1989/90), 50 (1993/94) and 55 (1999/00)[4] were compiled from the National Sample Survey Organization, New Delhi (India 1984, 1991, 1995, 2001b) and converted from raw data to the required format using the SPSS 10.0 computer programme. Data sets from the National Sample Survey Organisation have been arranged in terms of

[2] Income groups have been classified according to their expenditure levels.

[3] The 1998/99 Commodity-by-Commodity table is prepared from the make matrix and use matrix of the Central Statistical Office.

[4] Though the present study considered the 1998/99 input-output table, the data coverage of the National Sample Survey for that year is not sufficient to carry out a study. Thus, the National Sample Survey data for 1999/00 has been used, due to its extensive data coverage of more than 10 million households.

item code, expenditure on those items and then monthly per capita expenditure (specific item codes for different blocks and the required block levels for our purpose are extracted from the comprehensive data set). Data were arranged and sorted according to expenditure class, and further disaggregated by income group (lower, middle and higher). This classification was made for the year 1993/94. Consumption expenditure for the years 1983/84, 1989/90 and 1999/00 is provided at the respective year's prices. Necessary deflators have been used to study the income groups for the years 1983/84, 1989/90 and 1999/00 at 1993/94 prices. The income group classifications at those prices are as follows: the lower-income group comprises incomes of Rs 0 to Rs 6,000; the middle-income group, Rs 6,000 to Rs 12,000; the higher-income group, Rs 12,000 and above. These categories are used to disaggregate the sectoral private consumption expenditure recorded in the input-output table.

V. MODEL ESTIMATION AND ANALYSIS OF RESULTS

Results based on model 1

Model 1 is used to examine the emission levels of CO_2, SO_2 and NO_x. Aggregated hybrid input-output tables for the years 1983/84, 1989/90, 1993/94 and 1998/99 have been used to compute direct and total emission coefficients using equation (A1), provided in the annex.

Total emissions

The total industrial CO_2, SO_2 and NO_x emissions have been calculated using the input-output data for the respective years. Total emissions for the three air pollutants were computed using equation (4) of the model (see annex).

Table 1. Total emissions of carbon dioxide, sulphur dioxide and mono-nitrogen oxides, selected years
(Millions of tons)

Years	Total emissions		
	Carbon dioxide	Sulphur dioxide	Mono-nitrogen oxides
1983/84	369.50	2.69	4.98
1989/90	588.41	4.04	8.86
1993/94	759.44	5.63	9.91
1998/99	1 150.95	8.53	15.32

Source: Author's calculation, based on data from India (1990, 1997a, 2000b, 2005), using model 1.

It is evident from table 1 that emissions of all three pollutants tended to increase over the period covered; those increases can be seen clearly in table 2.

Table 2. Growth rate of emissions in India during 1983/84 to 1998/99
(Percentage)

Period	Total emissions		
	Carbon dioxide	Sulphur dioxide	Mono-nitrogen oxides
1983/84 to 1989/90	59.24	50.18	77.91
	(7.26)	(9.83)	(2.96)
1989/90 to 1993/94	29.06	39.35	11.85
	(5.81)	(7.87)	(2.37)
1993/94 to 1998/99	51.55	51.50	54.59
	(10.31)	(10.3)	(10.91)
1983/84 to 1998/99	211.48	217.10	207.63
(15 years)	(14.09)	(14.47)	(13.84)

Source: Author's calculation based on data from India (1990, 1997a, 2000b, 2005), using model 1.
Note: Terms in parentheses denote average increase per annum.

Levels of all three emissions, especially NO_x, increased significantly during the first period considered, but the rate of increase declined quite a bit in the second period. During the third period, growth rates of emissions were high once again.

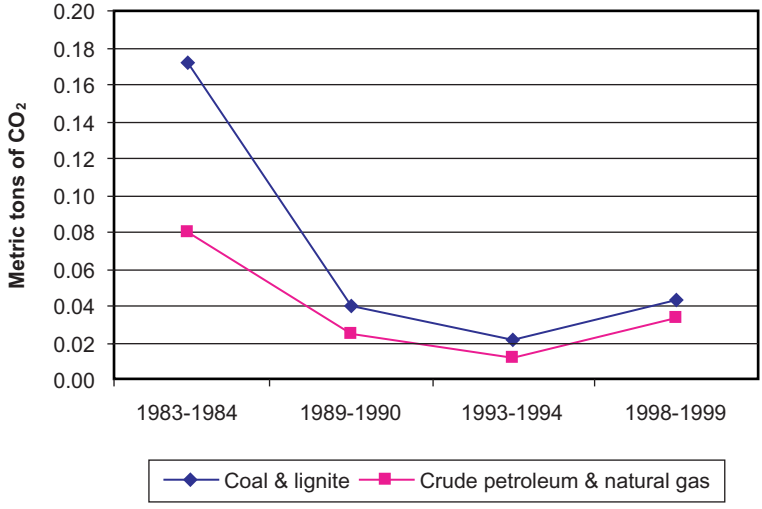
Sector-specific intensity of major pollutants during selected periods

The overall sector-specific direct and total requirements of CO_2, SO_2 and NO_x were high for energy sectors, particularly the coal and lignite, crude petroleum and natural gas, and electricity sectors. Of these, the electricity sector, which is based largely on coal, had both the highest total intensity and the highest direct intensity of CO_2, SO_2 and NO_x. The use of higher grades of coal, which release less CO_2, could lower the CO_2 intensity coefficient of the electricity sector.

A comparison of two periods (1983/84 to 1989/90 and 1989/90 to 1993/94) shows that the total intensity value was higher in the first period; it then dropped, maintaining somewhat lower levels (figure 1). The composition of the contribution of energy sectors towards total requirement of CO_2 underwent changes over time. A sharp fall in the values of crude oil petroleum and natural gas in the period before 1991 is observed; the values then stabilize, during a period of economic reform in India (figure 2). The drop was due to the increase in the direct and

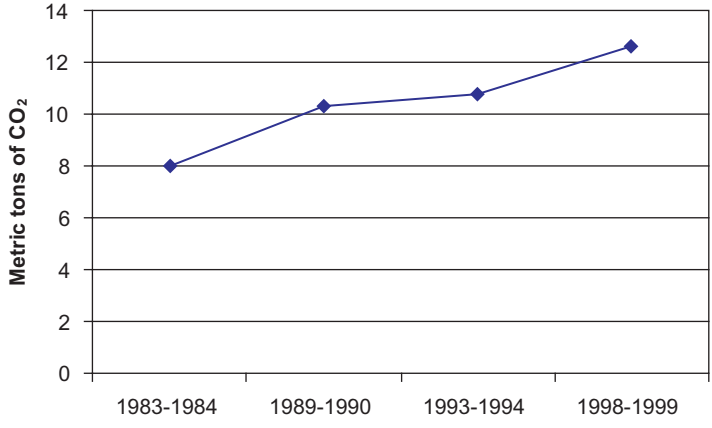
intermediate use of electricity in the economy. But values picked up again in the latter half of the 1990s. The growth pattern of CO_2 emissions in the coal sector remained similar to that in crude oil and natural gas (figure 1).

Figure 1. Total intensity of carbon dioxide in coal and crude petroleum and natural gas



Source: Based on the results from model 1.

Figure 2. Total intensity of carbon dioxide in electricity



Source: Based on the results from model 1.

Among other energy intensive sectors, construction sector emissions fluctuate throughout the period under consideration, but cement has improved. Improvement in the cement sector occurred in conjunction with the installation of relatively expensive new technologies, such as pre-calcining facilities, high efficiency roller mills and variable speed motors. The improved technology and the greater efficiency it affords served to lower the sector's intensity of carbon emissions. The direct intensity of the construction sector was the lowest among all sectors, because it does not take much fossil-fuel-based energy to construct a building or a road. However, the sector uses many energy-intensive materials, such as bricks, cement, iron, steel, aluminium, glass and asbestos, which translates into a high value of total CO_2 intensity. Other sectors that reflect such an indirect effect include textiles, trade, agriculture and transport. Given their higher values for indirect coefficients and larger volumes of activity, those sectors were responsible for the most CO_2 emissions in India in terms of total (direct and indirect) emissions due to final demand.

The direct SO_2 emission coefficients tended to be higher for sectors such as petroleum products; electricity; chemicals and chemical products; basic metal, metal products and machinery; trade; and other services, but they varied among periods. In terms of the coefficients of direct NO_x emissions, the electricity sector contributed more than any other sector. The rate of the emissions increase in most sectors dropped slightly, except in the iron and steel sector. The total emission coefficient of NO_x shows that the electricity sector was responsible for the highest increase. The coal and lignite sector and the crude oil sector also ranked relatively high.

Results based on structural decomposition analysis

The total changes in estimated CO_2, SO_2 and NO_x emissions from 1983/84 to 1998/99 have been decomposed into effects caused by three components: emission intensity (S),[5] technical coefficient (R), and final demand (Y), following equation (11), provided in the annex.

The results of these SDAs are shown in table 3. The rate of total changes in CO_2 and NO_x emissions dropped slightly during the second period (1989/90-1993/94). But the growth rates of all three pollutants increased during the latter half of the 1990s. The first term of equation (11), $\Delta S\, R_t\, Y_t$, reflects the CO_2, SO_2 and NO_x emission changes due to the changes in the intensity of these pollutants across various industries. The second term of equation (11), $S_0\, \Delta R Y_t$, defines the

[5] Emission intensity is considered as direct intensity, that is, emissions generated per unit of output.

CO_2, SO_2 and NO_x emission changes due to changes in technology calculated using the technical coefficient matrix. The third term of equation (11), $S_0 R_0 \Delta Y$, refers to the CO_2, SO_2 and NO_x emission changes due to changes in the final demand of various industries.

As shown in table 3, changes in total CO_2 emissions during the pre-reform period (1983/84 to 1989/90) were due mainly to the change in final demand (about 60 per cent). Change in technology was also responsible, but to a lesser extent (about 36 per cent). Change in intensity level (about 4 per cent) had only a small influence. The scenario changed drastically during the period 1989/90 to 1998/99. During this reform period, the share of intensity change increased, adding to total CO_2 emissions, whereas the much stronger influence of the technological factor served to reduce the increase in total emissions. On the other hand, the effect of change in final demand increased, thus aggravating emission levels during the economic reform period.

Table 3 shows that total emissions of SO_2 increased overall between 1983/84 and 1998/99, primarily due to changes in final demand and in intensity. The increase in total emission change would have been greater had it not been for the negative change in the technology factor.

Table 3. Structural decomposition analysis of carbon dioxide, sulphur dioxide and mono-nitrogen oxides during the period 1983/84 to 1998/99

(Millions of tons)

Period	*Pollutants*	*Total emission change (ΔTE)*	*Comparative static change*		
			Change in intensity ΔS)	*Change in technology (ΔR)*	*Change in final demand (ΔY)*
1983/84 to 1989/90	CO_2	227.47	9.23	77.69	131.99
	SO_2	1.35	0.02	0.40	0.93
	NO_X	3.88	0.36	1.68	1.84
1989/90 to 1993/94	CO_2	171.03	54.99	-185.82	301.86
	SO_2	1.59	1.02	-1.39	1.96
	NO_X	1.05	-1.54	-2.15	4.74
1993/94 to 1998/99	CO_2	391.51	131.48	-30.83	290.75
	SO_2	2.90	2.71	-2.98	3.23
	NO_X	5.41	2.89	-2.09	4.62

Source: Author's calculation based on model 1.

The analysis of NO_x (table 3) shows that the total emission change fell during the period 1983/84-1993/94, from 3.88 million down to 1.05 million tons, and that this was due to greater-than-proportionate decreases in the intensity and technology factors. During that period, increases in final demand—which was up from 1.84 million to 4.74 million tons—were outweighed by the other two factors. But the picture changed completely during the period 1993/94-1998/99, and final demand became the stronger influence.

Change in intensity

As shown in table 3, changes in intensity throughout the period 1983/84 to 1993/94 were positive for all sectors. This indicates that industries were using energy-intensive technology or were emission intensive. Direct- and total-intensity results reveal that the electricity sector had the highest CO_2 emissions. This was due to the large amounts of low-grade coal consumed and the inefficiency of the process of coal-produced electricity (Mukhopadhyay and Chakraborty 1999). The direct and total intensity results show that the transport, iron and steel, and construction sectors increased their CO_2 emissions significantly. The intensities of SO_2 and NO_x emissions followed a pattern of change similar to that of CO_2, except in the second period, when the intensity of NO_x contributed negatively. Changes in intensity further increased during the period 1993/94-1998/99.

Change in technology

The effect of the rate of change in technology on CO_2, SO_2 and NO_x emissions was positive up to 1989/90, but in the reform period it became negative. This drop was attributable to a shift to a more moderate consumption of coal (4.8 per cent per annum) and crude oil (5.6 per cent per annum) during the period 1991/92-1996/97 (Mukhopadhyay 2002). In the oil sector, technical changes that minimized the risks of exploration and facilitated an optimal mix of exploration, energy conservation and interfuel substitution had taken place. In the coal sector, technologies that have increased the efficiency of exploration, exploitation, utilization and mining have played an important role (Mukhopadhyay 2002). In fact, the change in emissions due to technology occurred largely in the electricity sector. This was due to the low thermal efficiency of power plants in India, which are generally small. The low capacity utilization of thermal power plants also decreased overall energy efficiency. The average annual load factor of all thermal plants in India was 53.8 per cent in 1990/91. This is largely attributable to inefficient operation and maintenance (India 1992).

Moderate technical changes helped reduce energy consumption, particularly in the coal and oil sectors, which in turn lowered emissions. New technologies for mining coal were introduced with a fair degree of success. The slight technical improvement in the oil and natural gas sector was possible due to the minimization of the risks of exploration in different basins in India. Vigorous measures for energy conservation and interfuel substitution have also been taken. The creation and utilization of capacity in the oil sector was very low in the 1980s, but improved substantially, particularly in the early 1990s. Due to technical improvement in capacity utilization, the growth rate of crude throughput also performed well, reaching 58.6 per cent in 1995/96 (4 per cent higher than in 1991/92) (Mukhopadhyay 2002). The trend in technological change was not significant during the period 1993/94-1998/99. However, alternative technologies introduced by the top polluting industries helped reduce emissions to some extent during that period. Various environmental policies adopted and implemented by the Government of India also contributed to the reduction (Mukhopadhyay 2002).

Changes in final demand

Changes in the final demand dominate all other factors. For all pollutants, the contribution of this factor doubled between 1989/90 and 1993/94. This is attributable to high energy consumption by the final demand sector: 6.9 per cent more energy per year was consumed during the 1993/94 period, as compared to the 1989/90 period. The increment was similar during the 1993/94-1998/99 period. The proportions of increase attributable to individual sectors were 9 per cent for coal, 5.47 per cent for crude oil and natural gas and 7.85 per cent for electricity.

The demand for electricity expanded rapidly in the household sector, as the pressure of urbanization continued to increase and the availability of consumer durables continued to expand. Several of the relatively newer and faster-growing industries, such as gems and jewellery, garments and electronics, were more energy intensive. The rapid pace of urbanization and diverse urban-growth patterns involved many basic structural changes to the economy, which in turn had major implications on energy use and CO_2 emissions. Urbanization brought changes in the way resources were collected, distributed and used. The rising per capita income associated with urbanization increased demands for both end-use energy and energy-intensive products and services.

Overall, the most important factor is changes in final demand, the aspect that dominates throughout. It reflects the increase in household consumption as well as that in other final demand components, such as Government consumption and imports and exports. As stated above, household energy consumption is increasing, and the pollution generated from it cannot be ignored. Thus, we estimate

the emissions generated by households, covering different income groups and the contributions of the responsible factors, as shown below.

Results based on model 2

Household energy consumption trends

Before focusing on the contribution of household emissions by income group, we highlight the commercial energy consumption pattern of the household sector in India during the period 1980-2000.

The household sector is responsible for a significant proportion of total primary energy use in India. Commercial energy use increased by almost four times between 1980 and 2000, from 323 to 1,257 petajoules. This reflects a change in the fuel mix. By 2000, the portion of secondary energy use was about 3 times that of 1980 levels (table 4).

Table 4. Household commercial energy consumption, 1980-2000
(Petajoules)

Energy carrier	*1980*	*Percentage of total*	*1990*	*Percentage of total*	*2000*	*Percentage of total*
Kerosene	234.67	72.50	380.48	63.68	559.17	44.46
Liquefied petroleum gas	53.79	16.62	111.75	18.70	286.37	22.77
Electricity	35.22	10.88	105.2	17.60	411.91	32.75
Total	**323.68**	**100.00**	**597.43**	**100.00**	**1 257.45**	**100.00**

Source: Reddy (2004).

Disparities in household energy use exist between high- and low-income groups in India. Energy consumption (1983-2000) demonstrates various characteristics. In urban areas, kerosene, electricity and liquefied petroleum gas (LPG) were the major energy carriers, used for purposes such as cooking, water heating and lighting. Many households once used wood for those purposes.

The income of a household influences energy consumption in many ways. With increased income, fuel price is less of a constraint. Households prefer to use a convenient form of energy, such as LPG. Due to the use of efficient devices, the total consumption of energy will not increase significantly. High-income households have opted for "modern" energy carriers such as electricity or LPG. Many

households use a mixture of modern and traditional fuels, each matched to a specific end use, such as cooking with LPG and heating water with electricity. High-income households also purchase other high-grade fuels, such as electricity, which are used for a greater variety of end uses (other than heating), such as air conditioning and refrigeration. Structural differences in energy carriers for cooking, lighting, transport and other durables are observed among different income categories in India.

As the data show (table 4), the contribution of the various energy carriers to the energy mix vary according to income group. With increasing disposable income and changes in lifestyles, households tend to move up the energy ladder (in terms of quality, convenience of use and cost): from biomass to kerosene and then to LPG/electricity. The energy consumption patterns of urban households change significantly, possibly due to the increase in the various appliances, such as televisions, microwaves and air conditioners. The main factors that determine the selection of energy carriers include: the prices of fuels and the corresponding utility devices; the disposable income of households; the availability of fuels; and cultural preferences (Reddy and Reddy 1994). With technological advances, associated end-use devices are also moving in the same direction. But inefficient energy use is significant in most cases.

Reddy (2004) observes a positive relationship between growth in per capita income and household demand for commercial fuels. In most developing countries, demand for commercial fuels has risen more rapidly than per capita incomes since 1970. This reflects an increasing desire for comfort as well as discretionary energy consumption. Reddy (2004) observes an association between occupation and energy use: attaining higher employment status is correlated with a shift to modern energy carriers. However, this is applicable largely to urban regions where the availability of modern energy carriers is high. For example, 45 per cent of the households in the mid-level employee category use LPG. Similar results were found for other categories also (table 5).

Causes of emission changes, by income group

The changes in intensity are identified for each group in table 6. The overall intensity effect increased sharply from the first period (1983/84 to 1989/90) to the second period (1989/90 to 1993/94) but the contributions made by each of the three groups significantly declined. The change-in-intensity value was inflated by the other final demand components, including exports, imports and Government consumption expenditure. In the first period, the negative contribution of the other final demand elements helped reduce the overall change in intensity of CO_2, SO_2 and NO_x. By the following period, the negative value of change in this area was

Table 5. Energy use by occupation
(Percentage)

Occupation	Biofuels	Kerosene	Electricity	LPG	Total
Executives	15.76	11.64	1.90	70.70	100
Middle-level employees	30.82	22.25	1.41	45.51	100
Lower-level employees	42.71	18.41	0.88	38.00	100
Labourers	56.87	24.81	1.10	17.23	100
Others	48.51	18.81	0.67	32.00	100

Source: Reddy (2004).
Abbreviation: LPG, liquefied petroleum gas

Table 6. Contributions of lower-, middle- and higher-income groups to changes in intensity of carbon dioxide, sulphur dioxide and mono-nitrogen oxide emissions
(Millions of tons)

Period	Pollutants	Change in intensity (ΔS)	Comparative static change			
			Lower-income groups	Middle-income groups	Higher-income groups	Other final demand components
1983/84 to	CO_2	9.23	12.036	53.89	100.50	-148.64
1989/90	SO_2	0.02	0.234	-1.335	1.03	0.099
	NO_X	0.36	0.112	-0.564	0.815	1.154
1989/90 to	CO_2	54.99	10.88	26.59	39.99	-22.48
1993/94	SO_2	1.02	0.025	-0.034	1.005	0.029
	NO_X	-1.54	0.003	-1.234	0.607	-0.924
1993/94 to	CO_2	131.48	11.27	46.68	54.81	18.70
1998/99	SO_2	2.71	0.026	-0.06	1.37	1.36
	NO_X	2.89	.023	-1.29	1.83	2.37

Source: Author's calculation, based on model 2.

much smaller. It follows, then, that the other final demand components are becoming more pollution-intensive. This may be due to final consumption expenditure of the Government, or exports.

The increased intensity effect during the study period of 1993/94 to 1998/99 was distributed among all income groups, reflecting an increasing trend. The higher-income group contributed 41 per cent of the CO_2 emissions, the middle-income group 35 per cent, and the rest was distributed among lower and

other final demand elements. During the whole study period (1983-1999), the change in the emission intensity of lower-income groups fluctuated, reaching a high of 12.03 and a low of 10.88. In the middle-income group, intensity declined during the period 1989/90 to 1993/94, but increased again in the next period (1993/94-1998/99), despite the reform strategy on energy implemented by the Government of India. The higher-income group was responsible for this increased intensity effect, which in turn was the main driver behind the increase in emissions.

As noted above, technological change helped improve the situation during the period under consideration. The influence on overall technical change varied according to income group, as shown in table 7; the higher-income group had the most influence. The overall contribution attributed to change in technology was positive in the period 1983/84 to 1989/90, but negative in the other two periods studied. The greatest fluctuation was in the category of other final demand elements. For the period 1993/94 to 1998/99, the technology effect reduced all the three emissions.

Table 7. Contributions of lower-, middle- and higher-income groups to changes in technology of carbon dioxide, sulphur dioxide and mono-nitrogen oxide emissions

(Millions of tons)

Period	*Pollutants*	*Change in technology (ΔR)*	*Comparative static change*			
			Lower-income groups	*Middle-income groups*	*Higher-income groups*	*Other final demand components*
1983/84 to 1989/90	CO_2	77.69	5.33	-7.21	-13.11	92.66
	SO_2	0.40	0.097	-0.054	0.853	-0.407
	NO_X	1.68	0.004	-0.076	1.012	0.756
1989/90 to 1993/94	CO_2	-185.82	-15.76	-41.29	-78.33	-50.25
	SO_2	-1.39	0.016	-0.97	0.045	-0.49
	NO_X	-2.15	0.17	-1.97	0.153	-0.52
1993/94 to 1998/99	CO_2	-30.83	-1.81	-21.72	-36.65	29.35
	SO_2	-2.98	1.02	-0.058	-2.85	-1.092
	NO_X	-2.09	-1.09	-2.58	-1.12	2.78

Source: Author's calculation based on model 2.

The contribution attributed to the change in final demand is the highest among all change factors (table 8). The contribution of the lower-income group was reduced slightly in this respect, but slight increases in the middle-income

group and more significant increases in the higher income group kept the overall values high. The patterns revealed after combining the contributions of each factor are similar to the patterns of the individual factors. During the period 1993/94-1998/99, the change in final demand for CO_2 was slightly lower, but slightly higher in the case of SO_2; the change in final demand remained steady for NO_x. The higher-income group contributed the bulk of the increase in emissions (61 per cent) in regard to this factor. A negative change in other final demand elements helped reduce the overall change in emissions.

Table 8. Contributions of lower-, middle- and higher- income groups to changes in final demand of carbon dioxide, sulphur dioxide and mono-nitrogen oxide emissions

(Millions of tons)

Period	*Pollutants*	*Change in final demand (ΔY)*	*Comparative static change*			
			Lower-income groups	*Middle-income groups*	*Higher-income groups*	*Other final demand components*
1983/84 to	CO_2	131.99	23.52	58.19	81.99	-31.79
1989/90	SO_2	0.93	0.431	0.219	0.607	-0.268
	NO_X	1.84	0.006	0.007	0.765	1.066
1989/90 to	CO_2	301.86	14.41	65.01	129.44	92.72
1993/94	SO_2	1.96	0.015	0.218	1.004	0.739
	NO_X	4.74	0.125	0.649	1.903	2.066
1993/94 to	CO_2	290.75	14.92	114.15	177.39	-15.72
1998/99	SO_2	3.23	0.015	0.38	1.37	1.46
	NO_X	4.62	0.129	1.139	2.607	0.74

Source: Author's calculation based on model 2.

In the case of middle- and higher-income groups, the trend of the contributions of different factors remains almost same for all periods. The only notable point is the shift in the intensity effect, the contribution of which decreases during the study period. The trend in the lower-income group was quite different. In the case of SO_2 emissions, the contribution of the lower-income group fell sharply during the study period. A change in the relative influence of responsible factors (changes in intensity and changes in technology) was observed in the middle-income group. A steady growth in the contribution attributable to each factor was observed for higher-income groups, except with regard to the technological change factor, which was comparatively higher in the first period than in the third.

Levels of change in NO_x emissions were greatest in the higher-income group, regardless of the factor. The contribution of the middle-income group was negative and not as significant in the first period, but the same contribution increased subsequently during the other subperiods. The contribution of the lower-income group was negligible in all three periods.

As noted in the introduction to the present paper, somewhere between 25 and 33 per cent of the global burden of diseases can be attributed to environmental factors. This proportion is larger in conditions of poverty, where more environmental hazards are present in the living and working environments, people have less capacity to protect themselves against exposure and effects of harmful and unpleasant pollutants, and the environmental threats tend to be more directly hazardous to human health. The incidence of poverty is high in India; about one third of the population is below the poverty line and largely affected by environmental hazards.

However, the overall assessment from the figures above reveals that the contribution made by the lower-income group to changes in emissions was not significant, and that the higher-income group dominated for all emissions and almost all factors. According to the present study, the higher-income group was responsible for generating more than 75 per cent of the change in emissions; 20-22 per cent was attributable to the middle-income group. Unfortunately, it is the lower-income group that suffers seriously due to pollution.

VI. CONCLUSION AND POLICY IMPLICATIONS

In the current study, we estimated the emissions of CO_2, SO_2 and NO_X in India for the period 1983/84 to 1998/99. We investigated the changes in emissions and the effects of various sources of change in industrial CO_2, SO_2 and NO_X emissions using input-output SDA. Further, we examined the contribution made by different income groups to those emissions.

The present analysis was based on an input-output, SDA approach. The data used were input-output tables for various years, aggregated into 47 sectors from 115 sectors, at constant 1993/94 prices. Our framework assumed fixed-coefficient Leontief technology, which is a special case of constant elasticity of substitution of production function. The effect of the assumption of fixed coefficient production function on the results is much discussed in the literature (Economic Systems Research, various issues). However, this assumption is not likely to affect the results in the present paper as we have considered the effect of change in technology over time in the decomposition analysis and no future forecast is made based on an assumption of fixed coefficient technology.

The study showed that the industrial emissions of air pollutants increased considerably in India during the period 1983/84 to 1998/99 (14.06 per cent per annum for CO_2, 14.47 per cent per annum for SO_2 and 13.8 per cent per annum for NO_x). The main factors for these increases were the changes in the final demand throughout the period. The change in intensity also increased, quite considerably, from 9.23 to 54.99 (between 1983/84 and 1993/94) and jumped again to 131.48 (between 1993/94 and 1998/99). The change in technology was also positive and quite significant in the first period, but had a negative effect on emissions in the second period. This reduction continued in the third period, at a less significant rate. These effects helped reduce the total changes in emissions for the second period.

The results of decomposition showed that, during the period covered, the Indian economy was moving towards more energy- and pollution-intensive industries. Though attempts to integrate more efficient technology into the economy were being made, the growth of energy consumption, its intensity and the technology effect failed to achieve the target of the reforms.

Results of the different income groups revealed that the higher-income households were responsible for most changes in emissions. This was due to their high levels of energy consumption. The middle-income group also contributed. However, the lower-income group was a minor player. Considering the contribution by different income groups to different change factors, the higher-income groups had the greatest influence on the intensity and the final demand effect. The contribution of the middle-income group was also considerably higher than that of the lower-income group. On the other hand, the technology effect was significantly negative, which helped reduce overall emission changes, though with fluctuations.

The overall assessment revealed that the lower-income group made an insignificant contribution to air pollution, while the higher-income group was a major source of all emissions with regard to almost all factors. The higher-income group tended to use commercial energy inefficiently, while households in the lower-income group were still not in a position to increase consumption of commercial energy. The income level of the average household had increased in India after reforms, but this increase was not reflected in the commercial energy consumption of the lower-income group. For this reason the contribution to changes in emissions by the lower groups was still negligible.

One of the greatest tasks at present is to tackle the generation of emissions by the higher-income group. The results of our study serve to help target pollution measures with respect to the four factors related to air pollution from fossil fuel combustion. We suggest that priority be given to energy conservation. The

Government of India must ensure strict implementation of the Energy Conservation Act (2001) in various levels of the economy, targeting change at the household level as well as at the industry level. Energy efficiency and conservation are possible through interfuel substitution, which can help mitigate the carbon problem. The main task is to increase awareness in the household sector regarding the efficient use of energy in cooking, lighting and transport.

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ANNEX

Model 1

Let C = C(j), (A1)

where C is a vector of fossil fuel emission coefficients representing the volume of CO_2, SO_2 and NO_x emissions per unit of output in different sectors (j). That is, dividing the sectoral volume of CO_2, SO_2 and NO_x emissions by sectoral output gives us the direct CO_2, SO_2 and NO_x emission coefficient. The direct and indirect carbon, sulphur and nitrogen emission coefficient of sector j can be defined as Cjrij, where rij is the (i, j)th element of the matrix $(I - A)^{-1}$. The direct and indirect CO_2, SO_2 and NOx emissions of a sector are defined as emissions caused by the production vector required to support final demand in that sector. This would depend not only on the direct and indirect emission coefficient of that sector but also on the level of sectoral final demand.

Emission model

Now, in equation form, CO_2, SO_2 and NO_x emissions from fossil fuel combustion can be calculated from industrial fuel data in the following manner:

$$F = C_t L1X = C_t L1(I - A)^{-1} Y \quad (3)$$

where F is a vector, representing the total quantity of CO_2, SO_2 and NO_x emissions from fossil fuel combustion only; C is a vector of dimension m (m x 1) of coefficients for CO_2, SO_2 and NO_x emissions per unit of fossil fuel burnt; L1 is a matrix (m x n) of the industrial consumption in energy units of m types of fuel per unit of total output of n industries; and t denotes the transpose of this vector.

In equation (3), C_t L1 = S represents only direct requirement of CO_2, SO_2 and NO_x intensities from industries, and C_t $L1(I - A)^{-1}$ gives the direct as well as indirect requirement of CO_2, SO_2 and NO_x intensities from industries. So, equation (3) explains the CO_2, SO_2 and NO_x emissions due to fossil fuel combustion from production activities in India.

Structural decomposition analysis approach

The total industrial CO_2, SO_2 and NO_x emissions (TE) can be expressed as:

$$TE = \Delta F = SRY = S(I - A)^{-1} Y, \quad (4)$$

where $R = (I - A)^{-1}$ and S represents the industrial CO_2, SO_2 and NO_x intensities.

According to the structural decomposition analysis method, the change in total CO_2, SO_2 and NO_x emissions between any two years, such as year 0 and year t, can be identified as:

$$TE = \Delta F = S_t (I - A_t)^{-1} Y_t - S_0 (I - A_0)^{-1} Y_0 \quad (5)$$

$$= S_t R_t Y_t - S_0 R_0 Y_0 \quad (6)$$

$$= S_t R_t Y_t - S_0 R_t Y_t + S_0 R_t Y_t - S_0 R_0 Y_0 \quad (7)$$

$$= \Delta S R_t Y_t + S_0 R_t Y_t - S_0 R_0 Y_0 \quad (8)$$

$$= \Delta S R_t Y_t + S_0 R_t Y_t - S_0 R_0 Y_{t-} + S_0 R_0 Y_t - S_0 R_0 Y_0 \quad (9)$$

$$= \Delta S R_t Y_t + S_0 \Delta R Y_t + S_0 R_0 Y_t - S_0 R_0 Y_0 \quad (10)$$

$$= \Delta S R_t Y_t + S_0 \Delta R Y_t + S_0 R_0 \Delta Y \quad (11)$$

The first term of equation (11) reflects the CO_2, SO_2 and NO_x emission changes due to the changes of CO_2, SO_2 and NO_x intensity in various industries. The second term of the equation defines the CO_2, SO_2 and NO_x emission changes due to the changes in the technical coefficient matrix. The third term refers to the CO_2, SO_2 and NO_x emission changes due to the changes in the final demand of various industries. Here, t refers to the current period and 0 defines the previous period.

It should be noted that only fuel NO_x was considered; thermal NO_x is not included here.

Model 2

The final demand vector Y was treated separately, by breaking down the total final demand as:

$$Y = Y_1 + Y_2,$$

where $Y_1 = Cl + Cm + Ch$ (12)

$$Y_2 = Y_2 \quad (13)$$

The term Cl carries the vector of household consumption belonging to lower-income groups; Cm, the vector of household consumption belonging to

middle-income groups; and Ch, the vector of household consumption belonging to higher-income groups. The term Y_2 signifies the vector of other final demand components, such as Government consumption, change in stock, investments, exports and imports.

We introduced equation (12) and (13) into equation (11) as follows:

$$= \Delta S\, R_t\, (Cl_t + Cm_t + Ch_t + Y_{2t}) + S_0\, \Delta R\, (Cl_t + Cm_t + Ch_t + Y_{2t}) + S_0\, R_0\, \Delta\, (Cl + Cm + Ch + Y_2) \quad (14)$$

The first term of equation (14), denominated as (14a), reflects the changes in intensity of CO_2, SO_2 and NO_x by considering the different final demand groups.

$$= \Delta S\, R_t\, Cl_t + \Delta S\, R_t\, Cm_t + \Delta S\, R_t\, Ch_t + \Delta S\, R_t\, Y_{2t} \quad (14a)$$

Likewise, the second term of equation (14), denominated as (14b), covers the changes in the technical coefficients of CO_2, SO_2 and NO_x by considering the different final demand groups.

$$= S_0\, \Delta R\, Cl_t + S_0\, \Delta R\, Cm_t + S_0\, \Delta R\, Ch_t + S_0\, \Delta R Y_{2t} \quad (14b)$$

Finally, the third term of equation (14), equation (14c), reflects the changes in final demand of CO_2, SO_2 and NO_x by considering the different final demand groups.

$$= S_0\, R_0\, \Delta\, Cl + S_0\, R_0\, \Delta\, Cm + S_0\, R_0\, \Delta\, Ch + S_0\, R_0\, \Delta\, Y_2 \quad (14c)$$

The contributions to CO_2, SO_2 and NO_x emissions from each income group and the category comprising the rest of final demand can be calculated using equations (14a), (14b) and (14c). Through this categorization we can estimate the degree of responsiveness of the responsible factors for all emissions among each income group:.

$$L = \Delta S\, R_t\, Cl_t + S_0\, \Delta R\, Cl_t + S_0\, R_0\, \Delta\, Cl \quad 15\ (a)$$

$$M = \Delta S\, R_t\, Cm_t + S_0\, \Delta R\, Cm_t + S_0\, R_0\, \Delta\, Cm \quad 15\ (b)$$

$$H = \Delta S\, R_t\, Ch_t + S_0\, \Delta R\, Ch_t + S_0\, R_0\, \Delta\, Ch \quad 15\ (c)$$

$$Y_2 = \Delta S\, R_t\, Y_{2t} + S_0\, \Delta R Y_{2t} + S_0\, R_0\, \Delta\, Y_2 \quad 15\ (d)$$

Equations (15 a, b, c and d) combine the total responsible factors effect for each income group.

UNIVERSAL HEALTH-CARE DEMANDS IN RURAL NORTHERN THAILAND: GENDER AND ETHNICITY

*Thitiwan Sricharoen, Gertrud Buchenrieder and Thomas Dufhues**

Thailand introduced a universal health-care scheme in 2001, initially with a co-payment of 30 baht (B) per physician's visit which was abolished by the military Government in 2006. The scheme covers 75 per cent of the Thai population. Nevertheless, it lacks flexibility for the beneficiaries as it is a one-size-fits-all scheme. In this study, choice-based conjoint (CBC) analysis is used to identify the health-care demands of different subpopulations in the Mae Rim district, northern Thailand. The different demands of subpopulations, such as men, women and ethnic minorities, are revealed through the CBC analysis. Most households would pay a co-payment higher than B 30 if the services were adapted to the demand, that is, if the quality of service were improved. In general, women appear more willing to pay a higher price than men if the benefits are improved accordingly. This means that men profit much more from the policy change of dropping the co-payment than do women. Furthermore, the present analysis indicates the need for more health education training, designed to meet the needs of the Hmong people in particular.

I. INTRODUCTION

Rural livelihoods are exposed to many risks in other words, they are vulnerable. This is particularly true for the poor, who frequently reside in rural areas. Among the many risks, those related to health have a particularly devastating

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effect on rural livelihoods. It is now widely recognized that a healthy population is a critical input into poverty reduction and economic growth (WHO 2001). The Government of Thailand has a long-standing commitment to providing its population with affordable health care. This is reflected by the high share of health care costs covered by public funds (61.6 per cent in 2003, 65 per cent in 2004) when compared to neighbouring countries (WHO 2006). In line with this, in 2001 Thailand became one of the first countries in Asia to introduce a so-called universal health-care scheme,[1] under which 75 per cent of the Thai population are insured (Hughes 2007).[2] The scheme is very popular among the Thai population; it has considerably improved access to health-care services and thus reduced health costs of the poor (Chamchan and Kosuke 2006; Coronini-Cronberg, Laohasiriwong and Gericke 2007; NaRanong and NaRanong 2006).

Despite the betterment of health-care coverage among the Thai poor, and the popular notion that the beneficiaries are happy with the services, Sricharoen (2006) and Coronini-Cronberg, Laohasiriwong and Gericke (2007) were among the first to suggest that the perception of satisfaction may not necessarily reflect reality. Lack of education, power imbalances or social concerns may have influenced the statements of beneficiaries with regard to the scheme. For instance, the universal health-care scheme, formerly known as the "30-baht" health-care scheme, was and still is inseparably connected to former Prime Minister Thaksin Shinawatra (2001-2006), who remains very popular among the poor and the rural population in general. Therefore, those beneficiaries may have assessed the scheme quite positively, overlooking its flaws.

[1] Sri Lanka introduced free and universal health care in the 1940s, and in 1996, Mongolia established its Social Welfare Law, which reflects the Government's commitment to, among other things, universal health care. The Economic and Social Commission for Asia and the Pacific (ESCAP) interprets universal coverage of health care as a situation in which (a) at the very minimum there exists equality in actual use of health services between rich and poor households, and (b) no household is forced to make impoverishing payments in order to receive a basic minimum level of acceptable health services (ESCAP 2007).

[2] Prior to the bloodless military coup in September 2006, people who had registered for the universal "30-baht" health-care scheme received access to medical services for a co-payment of B 30 (about $0.80 in October 2006) per person and per physician's consultation. After the coup, the military regime abolished the co-payment (see Apiradee Treerutkuarkul, "30-baht treatment to be made free", *Bangkok Post,* 13 October 2006). In December 2007, a national election was held and the military regime ceded power to a democratically elected civilian Government. The data collection for this research took place in 2004) and hence did not consider this policy change. However, this does not diminish the findings or the interpretation of our results. Only the conclusion and policy recommendations had to be adapted to the new situation.

The scheme has a number of well-known problems: (a) service is slow; (b) there is no service in a non-registered hospital; (c) coverage does not include all illnesses; (d) patients have difficulty obtaining a referral to another hospital registered under the health-care scheme; (e) access to medication under the scheme is not satisfactory; and (f) no service is provided without the appropriate card (Sricharoen 2006). Furthermore, many people have voiced their concern about the inadequacies of hospitals and health staff, especially physicians in small public hospitals (NaRanong and NaRanong 2006).

Considerations such as service quality and geographical access also need to be taken into account when trying to improve access to health-care services for the rural population. Due to the above-mentioned problems, some households opt out of the scheme altogether (Coronini-Cronberg, Laohasiriwong and Gericke 2007). Furthermore, the universal health-care scheme lacks flexibility for its beneficiaries, as it is a one-size-fits-all scheme. The diverse demands of various subpopulations are not addressed.

In the present paper, we evaluate the different health-care demands of population sub-groups, such as men, women, and ethnic minorities, within the framework of the 30-baht universal health-care scheme and offer policy recommendations to improve customer satisfaction.[3] A conjoint analysis is employed to determine the traits of a health-care scheme that are desirable for the rural population in northern Thailand, particularly in terms of the specific needs of men, women, and ethnic minorities, such as the Hmong. Conjoint analysis is a method of market research that combines quantitative and qualitative aspects and that is capable of assessing existing or hypothetical products and services.

In section II, we describe the data sample and provide a brief overview of the research area. In section III, we outline the relationship between vulnerability and the risk chain, which comprises the realization of a risk (shock), risk management and the outcome of the shock. The section includes an empirical risk assessment of the sample population. The formal health-care and health insurance system of Thailand is then briefly described in section IV. In section V, we present the conjoint analysis of the health-care scheme. A presentation of the model is followed by a summary of the results of a multinomial logit analysis. The paper ends with concise conclusions and policy recommendations.

[3] The present analysis yields meaningful results, despite the fact that the co-payment of 30 baht was dropped following the military coup in September 2006. In fact, the findings provide a scientific basis for discussing whether or not reinstalling the co-payment, possibly even at a higher rate, is reasonable. Furthermore, the findings are of value to countries debating whether to start or reform similar health-care schemes.

II. DATA SAMPLE AND RESEARCH REGION

In the present section, we will describe our data sample and the research region, and then discuss some key parameters (summarized in table 1) related to our survey in the regional context of northern Thailand.

Table 1. Background variables of sample households

	Gender					
	Men (n = 106)		*Women (n = 94)*		*Total (n = 200)*	
	Number	*Percentage*	*Number*	*Percentage*	*Number*	*Percentage*
Ethnicity						
Northern Thai	71	67.0	75	79.8	146	73.0
Hmong	35	33.0	19	20.2	54	27.0
Household income per month						
< B 3 000 ($80)	22	20.8	14	14.9	36	18.0
B 3 001-B 5 000 ($80-$133)	40	37.7	41	43.6	81	40.5
B 5 001-B 10 000 ($133-$267)	33	31.1	23	24.5	56	28.0
B 10 001-B 15 000 ($267-$400)	4	3.8	5	5.3	9	4.5
B 15 001-B 20 000 ($400-$534)	–	–	6	6.4	6	3.0
> B 20 001 ($534)	7	6.6	5	5.3	12	6.0
Type of health insurance of household						
Self-paid health expenses (no insurance)	2	1.9	2	2.1	4	2.0
30-baht health-care scheme	92	86.8	83	88.3	175	87.5
Social security health insurance	4	3.8	2	2.1	6	3.0
Old-age health insurance	7	6.6	2	2.1	9	4.5
Other	1	0.9	5	5.3	6	3.0
Doctor consultations in last 12 months						
< 2 times	54	50.9	43	45.7	97	48.5
3 to 4 times	21	19.8	17	18.1	38	19.0
5 to 6 times	15	14.2	16	17.0	31	15.5
7 to 8 times	4	3.8	2	2.1	6	3.0
> 8 times	12	11.3	16	17.0	28	14.0
Health care when slightly sick						
Do not cure	9	8.5	10	10.6	19	9.5
Own treatment	8	7.6	3	3.2	11	5.5

Table 1. *(continued)*

	Gender					
	Men (n = 106)		Women (n = 94)		Total (n = 200)	
	Number	Percentage	Number	Percentage	Number	Percentage
Buy drug from pharmacy	38	35.9	39	41.5	77	38.5
Traditional medicine	2	1.8	–	–	2	1.0
Public hospital	7	6.6	6	6.4	13	6.5
Private hospital	–	–	–	–	–	–
Local health-care unit	39	36.8	32	34.0	71	35.5
Clinic	3	2.8	4	4.3	7	3.5
Health care when severely sick						
Do not cure	–	–	1	1.1	1	0.5
Own treatment	–	–	1	1.1	1	0.5
Buy drug from pharmacy shop	2	1.9	–	–	2	1.0
Traditional medicine	–	–	–	–	–	–
Public hospital	78	73.6	76	80.9	154	77.0
Private hospital	6	5.7	2	2.1	8	4.0
Local health-care unit	15	14.2	12	12.8	27	13.5
Clinic	4	3.8	2	2.1	6	3.0
Other	1	0.9	–	–	1	0.5

Source: Sricharoen (2006).

The analysis is based on a survey conducted in the northern mountainous region of Thailand (Mae Rim district, Chiang Mai province) in 2004. The random sample covered 200 farm households in nine villages: 142 households belonged to the local ethnic group known as Northern Thai and 58 belonged to the Hmong group, often referred to as a hill tribe.[4] Of the sample households, 29 per cent belong to the Hmong minority. A recent survey indicates that the Mae Sa watershed, which covers most of the Mae Rim district, had a share of 23 per cent of Hmong households (Schreinemachers and others 2008). Thus, it is reasonable to assume that the present sample is unbiased. Hmong people usually dwell at higher altitudes, own fewer assets and are considerably poorer and less educated than Northern Thais (see, for instance, Schreinemachers and others 2008).

[4] Unless otherwise indicated, all empirical results refer to Sricharoen (2006).

The annual income per household in the sample ranged from B 12,000 ($320)[5] to B 480,000 ($12,810). At an average household size of 4.5 persons, the annual average income per household member reached B 23,800 ($635) and B 33,000 ($880) per adult household member. The average annual income per person in the Chiang Mai province was B 48,720 ($1,193) for the year 2004 (Thailand 2006). The lower average income of our sample households is not surprising, as our sample does not contain any municipalities. Most poor people in Thailand still live in rural areas, particularly in the north and north-east. About 21 per cent of the rural population in northern Thailand is classified as poor (Thailand 2005). While our sample seems to be unbiased in terms of the whole research district, we may have a slight bias towards lower-income population sub-groups. However, as our research focuses on the rural population, this bias may be negligible.

Despite the relatively large share of Hmong in the sample, the use of herbal or traditional medicine has almost disappeared. In recent years, the Hmong people have abandoned their nomadic lifestyle. As a result of this change in lifestyle, a tremendous amount of traditional knowledge has been forgotten. This loss of information most likely includes knowledge about traditional herbal plants. However, the use of shamans is still wide-spread. Although Christianity was first introduced by missionaries to the Hmong in Thailand in the 1920s, many Hmong communities, especially in the rural areas, have chosen to preserve their traditional religion or practice a mixture of both. This plays an essential part in the survival of their culture and identity (Tomforde 2003).

Almost 88 per cent of the sample was registered with the universal health-care scheme. Participation levels in other forms of health insurance were negligible. The farmers, regardless of whether they had experienced ill health during the past year or not, were asked to rank their preferences for treatment. The most frequent first choice for medical treatment was the local health unit. Second was a State hospital, because of the universal medical care available there, particularly for severe illnesses. The third choice was purchasing medicine at the nearby pharmacy.

More than a third of the households had had to consult a physician between three and six times during the 12 months prior to the survey. Assuming that individuals in the very poor rural population activate their universal health-care card only when it is absolutely necessary, this figure is quite impressive and implies that the general health situation is rather bad.

[5] The exchange rate of 13 October 2006 has been used throughout the paper. The value of the Thai baht in relation to the United States dollar at that time was $1=B 37.50.

This could be explained in part by the wide-spread overuse of pesticides, and the careless handling of such substances by northern Thai farmers, which was first reported by Jungbluth (1997) and has thus far not changed. Reports on pesticide-related health damage are increasing. For instance, in a relatively recent case involving tangerine orchards north of Chiang Mai, pesticide residues were found in villagers' blood as well as in the area's soil and water (Cheewin Sattha, "Buffer zone to allay fears over pesticides—Ministry may impose ban on two chemicals", *Bangkok Post,* 15 November 2003). Rerkasem (2005) states that overuse of chemical fertilizers and pesticides is a serious threat to the environment as well as to human health. Furthermore, in the 1990s, the northern Thai provinces were the centre of one of the most rapid outbreaks of HIV/AIDS in all of Asia. In the five northern provinces, HIV/AIDS cases were almost seven times the national average, representing almost half the total cases in Thailand (Singhanetra-Renard 1999). Finally, malaria is highly endemic in the hill tribe areas in northern Thailand.

It also seems likely that the B 30 co-payment was not set high enough to discourage unnecessary visits to health-care facilities. The vast majority of respondents stated, however, that they would consult a public hospital by means of their health-care card only when severely sick. Otherwise, many people would just buy drugs on their own.

III. VULNERABILITY, RISKS AND RISK MANAGEMENT STRATEGIES

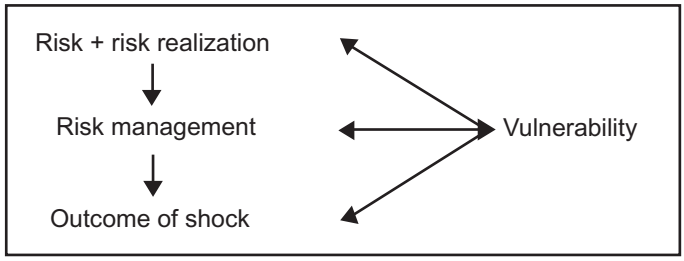
Vulnerability is the forward-looking state of expected outcomes, which are determined by correlation, frequency and timing of realized risks and risk management (IFPRI 2002). The term vulnerable could be applied to (a) a household that is not yet considered poor but may drop (with a given probability) below a certain poverty line in the near future; or (b) the livelihood of a household if it is below the poverty line and there are no chances (with a given probability) of overcoming poverty in the near future.

Vulnerability reduction requires a better understanding of risks, risk exposure, outcomes that are likely to be generated, and the most efficient means of managing risks (Alwang, Siegel and Jorgensen 2001). Rural health insurance and health-care schemes can play a key role in mitigating the negative outcomes from ill health, thus reducing vulnerability. Their relevance is reflected by the fact that 23 per cent of all risks reported in the present study are related to ill health.

Risk as a cause of vulnerability

The risk chain (figure 1) of vulnerable households consists of three components: (a) risk (realization), (b) risk management and (c) outcome in terms of welfare loss (IFPRI 2002). A shock is the realization of a risk that can cause significant negative effects on livelihood in general and the degree of vulnerability associated to livelihood.

Figure 1. The risk chain



Source: IFPRI (2002).

Livelihoods are exposed to multiple risks, both natural and human-made. Risks can be characterized by their magnitude (including size and spread), and their frequency and duration. Table 2 presents types of common risks, divided into human, economic and asset risks; some are considered idiosyncratic (individual) and some are considered covariate. Individual risks are those that, when they are realized and create a shock or crisis, affect just one person (one family or household). Health risks typically fall into this category; exceptions include epidemics. Correspondingly, risks changing the livelihood of a group of people bound together by the same profession (such as farming) or the same region of residence are called covariate risks.[6]

Of all of the risks listed in table 2, human risks such as illness and death of the main provider appear to be particularly prevalent and destabilizing (World Bank and DFID 1999). Nevertheless, not all types of risks can be insured against;

[6] Covariance is the tendency for either (a) many households to be affected by a risk at the same time, or (b) several risks to consistently occur together. Covariant or mass risks are significantly different than individual risks: (a) they tend to be difficult or impossible to predict; (b) they affect many people at the same time, thus hampering the ability of risk-pooling mechanisms to protect against these risks; and (c) the cost associated with mass covariant risks tends to be significantly greater than that which results from other risks (Brown and Churchill 1999; Dercon 2002).

Table 2. Covariate and idiosyncratic risks of vulnerable rural livelihoods

	Type of risk	*Type of shock*	*Outcomes*
Individual risks	Human	Illness	Costs of treatment and reduced income due to reduced labour
		Death of working family member	Funeral expenses and loss of income from labour
		Alcoholism, drug addiction, gambling	Expenditures of addiction and reduced income due to reduced labour
Covariate risks	Economic (harvest)	Storage loss: vermin and other pests	Reduced income
		Crop loss: land degradation (landslide, volcanic eruption, earthquake)	Reduced income
		Crop loss: weather (floods, droughts, typhoons, storms and high winds)	Reduced income
	Economic (non-harvest)	Domestic economic crisis (e.g. balance of payment shock, financial crisis, currency crisis)	Reduced income due to lack of trade and loss of employment, etc.
		Animal epidemic	Reduced income, assets and security
Individual risks		Death of animals	Reduced income, assets and security
		Failure of business/investment	Reduced income, failure to repay debts
		Unemployment	Reduced income
		Birth of daughter	Expenditures because of marriage
		Old age	Reduced income due to reduced labour
		Sudden relocation of working family member and breaking ties	No remittance flow
	Asset	Damage of housing	High expenditure
		Theft or being cheated	Loss of assets and costs of replacement

Sources: Extended from World Bank and Department for International Development (DFID) (1999) and Holzmann and Jorgensen (2000).

only risks with a known probability of occurrence and a high degree of specificity are suitable for insurance (Litzka 2002). In developing countries, usually only idiosyncratic risks are insured. Covariate risks are more difficult to insure; within a weak institutional framework it is almost impossible to design financially sustainable insurance instruments for such risks. In terms of idiosyncratic risks, health insurance is the protection most frequently sought in developing countries (Jütting 1999).[7] Although the universal 30-baht health-care scheme was often referred to as an insurance scheme, it did not display the typical characteristics of insurance. For example, the abolished co-payment was not a premium. Thus, a very basic principle of insurance was not fulfilled.

Risk management as part of livelihood strategies

Livelihood strategies differ according to whether people have to deal with gradual changes or sudden shocks. In line with this, risk management can take place at different moments—both before and after the shock occurs. Adaptive livelihood strategies seek to mitigate risks through livelihood adjustment, such as change and diversification of income-creating activities, or through family planning or accessing insurance. This type of strategy is rather deliberate and adjusts the livelihood to long-term changes and challenges (socio-economic trends). Adaptive strategies are applied before a risk materializes (ex ante risk management). Registering for the universal health-care scheme and thus gaining access to health-care services is just such a deliberate adaptive strategy. Coping strategies, such as migration, sale of livestock or reduction of consumption expenditures, seek to minimize the impact of livelihood shocks and are short-term, ex post responses to sudden or periodic shocks (Carney and others 1999, Korf 2002).[8] Though coping strategies do provide some protection in the short run, they also limit the poor's long-term prospects of escaping poverty (Kanbur and Squire 2001). In fact, the poor may experience irreversible negative effects. Holzmann (2001) suggests that the Government has an important role to play in helping the poor to cope.

[7] Most health insurance schemes in developing countries were started in the second half of the 1990s. For instance, in Cambodia GRET launched the famous SKY Health Insurance Program in 1998, which now covers more than 10,000 people (or more than 2,000 families). An interesting aspect of the SKY health insurance program is that it accepts only families, to avoid the risk that only the elderly or those more likely to be prone to ill health would seek insurance (see www.sky-cambodia.org/efirstresults.html).

[8] The other two livelihood strategies not mentioned in the main body of the text are the accumulation strategy and the survival strategy. The first refers to strategies that seek to increase income flows and stocks of assets, and the latter to strategies that aim to prevent destitution and death.

Adaptive livelihood strategies can be further differentiated into risk-reducing and risk-mitigating strategies (table 3). Holzmann (2001, 2003) calls this the risk management matrix. The four-by-four structure of the matrix highlights the multidimensional character of risk management. Filling in each cell of the matrix with existing instruments provides a means of examining the status of social risk management in a given country or region. It may thus help to compare countries and assess differences among them and to determine appropriate and useful changes.

While risk-reducing strategies aim to reduce the probability of a shock occurring, risk-mitigating strategies seek to reduce the impact of a shock to livelihood. Mitigating the effects of a shock through risk pooling requires, by definition, people to interact with other people, and poor people are typically less able to participate in both formal and informal arrangements. Insurance or insurance-like services, such as the Thai universal health-care scheme, classify as risk-mitigating livelihood strategies. In fact, the Thai universal health-care scheme is a public service that is not based on market considerations.

Health risks and risk management in rural northern Thailand

Health risks are often mentioned as being among the most threatening risks to sustainable livelihoods in developing countries. The beneficiaries of the universal health-care scheme that Thailand has been offering since 2001 are supposed to be mainly the poor and those excluded from other existing health insurance schemes. Given the high rate of health insurance coverage in Thailand—about 95 per cent of the population—health risks might rank relatively low in the people's perception of risks. Yet ill health and its related expenses still seem to pose huge risks for the livelihood of the rural poor in northern Thailand.

In our survey, rural inhabitants were asked about, among other things, the types of risk and shocks they encountered during the year preceding the survey. The farmers mentioned 194 shocks that fall into economic (harvest and non-harvest) and asset categories and 57 shocks related to ill health, that is, 23 per cent of all shocks. These shocks are also related to a total of 32 reported risks. Of the top 10 most often mentioned risks (noted by 81 per cent of respondents), three were related to health: (a) chronic disease of a non-working family member (6.4 per cent); (b) prolonged disease of a working family member (6.8 per cent); and (c) chronic disease of the head of household (3.6 per cent). Over 40 per cent of the 57 health shocks required expenses of up to B 5,000 ($133), which is 21 per cent of the average annual income per adult household member. Despite the vast coverage of the universal health-care scheme, almost 9 per cent of the shocks entailed outlays beyond B 50,000 (more than $1,300).

Table 3. Formal and informal risk management mechanisms

	Informal mechanisms		*Formal mechanisms*	
	Individuals and households	*Group based*	*Market based*	*Public services*
Reduce risks	• Health care • Migration • Secure income sources	• Joint infrastructure measures • Management of common natural resources	• Company-based and market-driven labour standards • In-service training	• Robust macroeconomic policy • Environmental policy • Education policy • Health policy • Infrastructure • Labour market policy • Labour standards
Mitigate risks				
Diversification/ portfolio	• Diversification of crops and plots • Diversification of income sources • Investment in physical and human capital	• Professional associations • Savings and credit associations	• Savings accounts with formal financial institutions • Microfinance	• Multi-pillar pension systems • Asset transfers • Protection of rights (i.e. women) • Support for extending financial services
Insurance	• Marriage and extended family • Share tenancy • Tied labour • Buffer stocks	• Investment in social capital	• Old age annuities • Insurance (accidents, health, fire, etc.)	• Mandated/ provided insurance (unemployment, ill health, etc.)
Cope with risks	• Sale of assets • Money-lender loans • Child labour • Reduced food consumption • Seasonal or temporary migration	• Transfers from mutual aid networks	• Sale of financial assets • Loans from formal financial institutes	• Social assistance • Work programmes • Subsidies • Social aid funds • Direct transfers

Sources: Holzmann (2003), Holzmann and Jorgensen (2000) and World Bank (2000).

Notes: The table is not complete, but serves as a reference. The area highlighted is of special interest for this paper, particularly with regard to health insurance.

Three risk groups were defined on the basis of annual risk management costs and average income per household member: low risk-management costs (< B 9,999; < $267), medium (B 10,000-B 39,999; $267-$1,067), and high risk-management costs (> B 40,000; > $1,067). Under this classification, the majority of health shocks (67 per cent) fell into the low-costs group. However, 42 per cent of the farmers stated that their health expenses still represented a relatively high burden on their household budgets.

IV. THE SOCIAL WELFARE AND HEALTH-CARE SYSTEM OF THAILAND

Thailand provides social insurance for sickness, maternity, disability, death, childcare, old age and unemployment. The social security system encompasses private-sector employees, public employees and military personnel. In 1994, the Workmen's Compensation Act[9] for the private sector was extended to cover work-related injuries, diseases, loss of organ(s), disability, death or disappearance. State employees are insured under separate schemes, which are similar to the system in the private sector. People not covered by any of these systems (often the informally and self-employed poor), could join the universal health-care scheme, which until 2006 entailed a co-payment of B 30 per person and per doctor's consultation. However, certain population groups had been exempted from the co-payment even before it was dropped. Those groups included children under 12 years of age, senior citizens aged 60 years and over, the very poor, and volunteer health workers (Coronini-Cronberg, Laohasiriwong and Gericke 2007).

The 30-baht health-care scheme sought to provide the same quality of health services as offered under other health insurance schemes, such as the Civil Servant Medical Benefit Scheme or the Workmen's Compensation Scheme. As such, it combined the previous social welfare health services and the voluntary health-card scheme. In 2001, those two services covered more than 53 per cent of the Thai population; still, 29 per cent of the 60 million people in Thailand were uninsured. With the introduction of the 30-baht universal health-care scheme, the percentage of the Thai population with access to health services reached 95 per cent. This scheme alone reached about 75 per cent of the population (Thailand 2003). Public hospitals were the main providers of health care under this scheme; they served 95 per cent of the insured. About 80 private hospitals were also registered under the scheme.

[9] This Act replaced Announcement No. 103 of 1974, prompting the establishment of the Workmen's Compensation Fund.

The universal health-care scheme in Thailand covers a wide range of services: (a) outpatient visits to a range of health service providers; (b) long-term illness, other chronic illnesses, and sickness related to old age; (c) medications and diagnosis; and (d) transfers from a local hospital to other hospitals in emergency cases. Nevertheless, the scheme covers only those drugs which are included in national drug lists. A certain range of specific conditions, such as infertility and drug addiction,[10] and certain procedures, such as obstetric delivery, haemodialysis and organ transplants, are not covered.

The universal health-care scheme is funded by the Government of Thailand out of tax revenues, with health-care providers being reimbursed on a capitation grant basis: the annual payment per capita in 2002 was B 1,404 (about $37); and in 2007/08 it was B 2,100 (about $70).[11] This is a considerable burden on the public budget. In its resolution 63/8 of 23 May 2007 on sustainable financing towards achieving universal health-care coverage in Asia and the Pacific, ESCAP noted the problematic issue of health care financing.

The universal health-care scheme in Thailand is very progressive in that it has provided insurance-like services to 75 per cent of the population. An impressive 88 per cent of the sample households participate in the scheme (see section II). Nevertheless, it is a heavy burden on the state budget, and its financial sustainability is a major issue. Whether the scheme can be made financially sustainable at all remains uncertain and is hotly debated among politicians and in the Thai press (Hughes 2007). While the co-payment surely created some revenues, the main objective of its existence was cost reduction. The co-payment was intended to reduce unnecessary visits to physicians and hospitals. Thus, it is all the more surprising that co-payments from universal health-care scheme beneficiaries were abolished altogether.

V. CONJOINT ANALYSIS OF UNIVERSAL HEALTH CARE IN NORTHERN THAILAND

Health-care schemes for the poor can be designed in various ways. This section serves to better understand which of the present (and past) attributes of the universal health-care scheme in Thailand have created the highest utility among

[10] The lack of coverage for infertility particularly affects women. Drug addiction is relatively frequent in northern Thailand, mainly caused by abuse of methamphetamines. However, some hill tribes still produce poppy for own consumption and, after years of decline, production seems to have increased again within recent years (see Subin Khuenkaew, “Return of the poppy” Bangkok Post, 14 July 2008).

[11] See the Thailand Board of Investment website at www.boi.go.th/english/how/sectors_detail.asp?id=93.

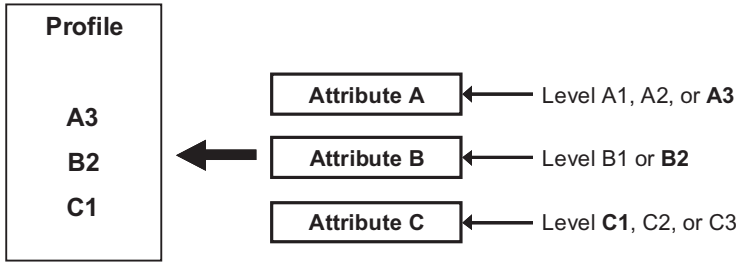
beneficiaries. The potential demand for alternative health-care designs is modelled for gender and ethnicity. Whether or not the rural population could be better served by a different design of the health-care scheme, possibly even with a higher individual financial contribution, is assessed by means of a choice-based conjoint (CBC) analysis. Modelling a demand-oriented future for a health-care scheme can possibly improve policy decisions with regard to the livelihoods and vulnerability of the rural poor.

The conjoint analysis model

Conjoint analysis is a multivariate technique used to estimate or determine the preference structures of consumers or clients for products or services (Hair and others 1998). It is often used in marketing research for consumer goods, though not as frequently for services. This type of analysis can provide information about bundles of attributes that represent a potential product or service. Every product or service possesses different attributes with different levels. Not all existing attribute levels are maintained for the market research. Different compositions of attributes and levels create hypothetical products or services (profiles). Figure 2 illustrates the relationship between attributes, their levels and their inclusion in a product/service sample.

The most important attributes of the health-care scheme and their levels are determined through expert interviews and qualitative and participatory research tools at the target group level. The stimuli to be presented to the target group describe distinct combinations of attribute levels that have been derived from statistical procedures. These profiles are ranked by respondents (target group) and analysed in a multinomial logit model. A componential segmentation analysis is carried out to establish a causal statistical link between the socio-economic

Figure 2. Relationship between profiles, attributes and levels in conjoint analysis



Source: McLennon (2002).

data of respondents and their ranking. Consumer preferences are reflected in their choices among product and service profiles and can be broken down to an individual attribute and its levels.

Conjoint analysis seeks to quantify and predict preferences for various levels of a multi-attribute product or service. The algebraic aspects of the conjoint analysis model are shown in the annex. The main characteristic distinguishing choice-based analysis from other types of conjoint analyses is that in the former, respondents express preferences by choosing from sets of profiles, rather than by rating or ranking them. The choice-based task is similar to what consumers actually do in the marketplace. Another advantage of the choice-based conjoint (CBC) method is the "none" option. As in the real world, respondents can decline to purchase in a CBC interview (Orme 1996). In our case, this means choosing "no coverage at all".

CBC applies multinomial logit estimation. This analysis results in a set of numbers that are comparable to conjoint utilities at the respondent level, but which differ in that they describe the preferences of a group rather than of an individual (Sawtooth 2006). The relative importance of each attribute is calculated to enable comparisons between attributes. To do so, the difference between an attribute's highest and lowest part-worth utility values from the multinomial logit model is calculated to establish the utility range for the given attribute. Once the utility ranges for all attributes are determined, the relative importance of each attribute is calculated by dividing the utility range for the attribute by the sum of all attributes (Hair and others 1998).[12]

Attributes and levels of choice-based conjoint analysis

Based on expert interviews and participatory group interviews with farm households, three attributes (and corresponding levels) were selected for the CBC analysis of a health-care scheme in northern Thailand. The three attributes are:

(a) *Co-payment per visit*. Under the former universal 30-baht health-care scheme, a registered household had to pay B 30 ($0.80) per hospital visit. The health-care products in this study are provided at three different prices: a base co-payment of B 30, a medium co-payment of B 60 ($1.60) and a higher co-payment of B 90 ($2.40).

[12] See annex for the underlying mathematical model.

(b) *Choice of health-care facility*. Available medical health-care institutions are local health-care units and public and private hospitals. The health-care units are located close to communities, thus they are easy to reach and enable users to economize on transportation costs. In Thailand, the existing universal health-care scheme is limited to registered hospitals, mainly public hospitals. The health-care concepts in this study provide potential customers with the option to access services at any hospital.

(c) *Health coverage level.* In terms of medication, the universal health-care scheme covers only that which is on the National List of Essential Drugs. However, farmers often mentioned this as being a major disadvantage. Therefore, medication not listed on the national drug list is included here as one attribute level.

In the present paper, the CBC analysis is presented for the whole sample, as well as for the background variables "gender" and "ethnic group". It is hypothesized that different utility functions will be exhibited according to the gender and ethnicity of respondents.

Preference analysis for a universal health-care scheme

In this section, we apply multinomial logit analysis to CBC data. A utility is a measure of relative desirability or worth. When computing utilities using logit, every attribute level is assigned a utility (also referred to as a part-worth). The higher the utility (part-worth), the more desirable the attribute level. Levels that have high utilities have a large positive impact on influencing respondents to choose a product (Sawtooth 2000). Conjoint analysis begins with the estimation of the part-worth utilities for the total sample. This entails examining the part-worth coefficients, as the size and sign indicate the degree and direction in which respondents prefer a particular level of an attribute.

Conjoint analysis is applied here to empirically identify the specific demand for universal health-care coverage. First, the different potential demands of women and men are discussed, then the distinct demands of two different ethnic minorities. Table 4 depicts the estimation results for all respondents and by gender. The multinomial logit analysis is evaluated by chi-square statistics. The chi-square test shows that the overall model is significant at the 1 per cent level. A t-test was used to test the null hypothesis that the part-worth estimates are equal to zero (McLennon 2002). The estimated coefficients for all attribute levels were significant at the 1 per cent level of confidence.

The results, shown in table 4, indicate that the co-payment attribute and the coverage attribute were determined the most important, each accounting for about 30 per cent of the preference rating. The attribute "freedom in selecting the health-care facility" came last, even lower than the "none" option. The present policy of the Thai universal health-care scheme of covering only medication listed in the National List of Essential Drugs is causing a substantial reduction in the part-worth utility, as indicated by the negative coefficient of -0.51. This indicates that the insured want more drug coverage.

Table 4. Multinomial logit estimation of average utility values for health-care attributes, by gender

	Gender				*Total*	
	Men *n = 106*		*Women* *n = 94*		*n = 200*	
	Effect	*t-ratio*	*Effect*	*t-ratio*	*Effect*	*t-ratio*
Co-payment						
B 30	0.89283	9.40704	0.40646	4.16365	0.65899	9.73349
B 60	-0.40433	-4.21172	-0.30719	-3.21073	-0.35371	-5.23762
B 90	-0.48850	-3.91823	-0.09926	-0.77046	-0.30528	-3.42456
Relative importance (percentage)	36.00		20.42		31.40	
Choice of health-care facility						
Registered hospital	-0.29079	-4.62447	-0.25621	-4.11994	-0.2708	-6.14989
Any hospital	0.29079	4.62447	0.25621	4.11994	0.2708	6.14989
Relative importance (percentage)	15.16		20.69		16.79	
Health coverage level						
Cover national drug list	-0.54642	-8.73810	-0.48373	-7.54752	-0.51472	-11.53250
Cover all drugs	0.54642	8.73810	0.48373	7.54752	0.51472	11.53253
Relative importance (percentage)	28.49		39.06		31.91	
No coverage	0.78076	8.35798	0.49148	4.99772	0.64184	9.52322
Relative importance (percentage)	20.35		19.84		19.90	
Chi-square	252.33		131.97		369.33	

Source: Sricharoen (2006).

Note: The chi-square test of the model is significant at the 1 per cent level. For the t-ratios, a value of 2.660 indicates significance at the 1 per cent level.

The relatively large coefficient (effect) for the attribute level "co-payment of 30 baht" suggests that this co-payment level is the most desirable of the attribute levels chosen in the study. The presence of this attribute will increase the perceived utility with a part-worth of 0.66. This could lead to the assumption that people care mostly about the private costs of health care. However, the picture changes with a look at the population's sub-groups.

Men and women have differing perceptions of the relative importance of co-payment attribute levels. Men place the highest relative importance on the co-payment attribute and perceive the highest utility from the B 30 co-payment. In comparison, women assign the highest relative importance to the health coverage attribute. This means that women are much more willing to compare the costs and performance of the health-care scheme. Clearly, they also appreciate a low price, but other attributes can outdo the importance of the price. Although it can be assumed that women have a lower average income than men, they opt more strongly for the higher co-payment profiles. This result can be interpreted only in connection with their preference for more choice when it comes to hospitals and medication. It appears that they are willing to pay a higher price if the benefits of the health-care scheme are improved accordingly.

Men also want to have better health-care services; they are, however, not prepared to pay a higher price for them. This may indicate that they prefer to keep the "cheap" health-care scheme, even if that means a cut in service. As the head of the household normally has to provide the household's livelihood, men may be reluctant to accept a higher per-visit co-payment, as this would apply to all of their family members. However, all income is traditionally given to the *mae baan*—usually the wife of the head of the household—who administers the family budget and redistributes money to individual household members. Therefore, another explanation could be that the awareness of health issues is generally much lower for men than women. For instance, data from Thailand (2004) indicate that Thai men have a much riskier lifestyle than women. Furthermore, women are usually in charge of dependent household members such as children and the elderly. Because of this responsibility, women may possess a much better perception about quality issues in heath-care schemes, as they are more often confronted with the above-mentioned quality problems of the scheme.

Finally, the most unexpected result is the rather high incidence of respondents that chose the "none" option, which means they chose no coverage at all. Unfortunately we have no data on why the respondents chose that option. Two groups of people come immediately to mind. First, the very poor; for them, even a B 30 co-payment per visit is probably still too high. The poor also place their highest relative importance on the co-payment attribute in comparison to

other income groups (Sricharoen 2006). The second group could belong to a higher income stratum. Those people do not care about co-payments of B 30 or B 90 per visit and may consider the scheme as insufficient across the board. Although women in particular suffer from the exclusion of obstetric delivery and the treatment of infertility in the universal health-care scheme, the relative importance of the "none" option does not differ between men and women.

Interestingly, the differences between the two ethnic groups (Northern Thai and Hmong) are not as pronounced as the differences between men and women (see table 5). Nevertheless, we identified a similar trend: Northern Thai people focused less on the co-payment attribute and more on the other two attributes. This implies that they would be more willing to make a higher co-payment provided

Table 5. Multinomial logit estimation of average utility values for health-care attributes, by ethnicity

	Ethnic group			
	Thai n = 152		*Hmong n = 58*	
	Effect	*t-ratio*	*Effect*	*t-ratio*
Co-payment				
B 30	0.55171	6.99642	0.96606	7.18961
B 60	-0.33927	-4.36678	-0.40062	-2.89172
B 90	-0.21244	-2.04742	-0.56544	-3.15642
Relative importance (percentage)	30.47		35.89	
Choice of health-care facility				
Registered hospital	-0.27386	-5.41386	-0.26591	-2.94277
Any hospital	0.27386	5.41386	0.26591	2.94277
Relative importance (percentage)	18.73		12.46	
Health coverage level				
Cover national drug list	-0.49188	-9.59796	-0.58966	-6.42129
Cover all drugs	0.49188	9.59796	0.58966	6.42129
Relative importance (percentage)	33.64		27.63	
No coverage	0.5021	6.32165	1.02493	7.79072
Relative importance (percentage)	17.17		24.02	
Chi-square	234.6509		150.0453	

Source: Sricharoen (2006).

Note: The chi-square test of the model is significant at the 1 per cent level. For the t-ratios, a value of 2.021 and 2.704 indicates significance at the 5 per cent and 1 per cent level, respectively.

that the service quality would be improved. The Hmong people are quite the opposite—they strongly focus on the co-payment attribute. This can be simply explained by the fact that hill tribes such as the Hmong are usually much poorer than the ethnic majority of Northern Thai (see also section II). As mentioned above, poorer people favour a lower co-payment more than any other attribute level.

While relatively the same number of men and women chose the "none" option, we observed a difference between the two ethnic groups in regard to this category. The high proportion of Hmong people who chose "none" is striking. This could be explained by the higher share of poor people among the Hmong minority. As noted, for extremely poor people, even B 30 can be too much. However, the data from Sricharoen (2006) neither support nor reject this interpretation. Alternatively, it may be due to an awareness problem regarding health coverage and the continued high use of informal medicine from people such as shamans and herbal healers. Such an awareness problem may also correlate with the lower educational status of the Hmong people (see section II). This finding could point to the need for an awareness campaign specifically designed to address less-educated hill-tribe people such as the Hmong.

VI. CONCLUSIONS AND POLICY RECOMMENDATIONS

Livelihoods in rural Thailand are prone to risks. One of the major risks that affect household incomes is ill health, as it is associated with lower income or higher expenses. In 2001, the Government of Thailand introduced a universal health-care scheme that provides access to medical services. Prior to the military coup in September 2006, each person registered under the scheme had to pay B 30 per doctor's consultation. This policy was intended to induce a feeling of adherence to the scheme, to reduce the number of those seeking medical treatment without reason, and to limit the high subsidization rate of the Government at least somewhat.

Nevertheless, the universal health-care scheme is associated with a number of problems. Whether or not the beneficiaries of the scheme could be better served by a different design, possibly even with a higher co-payment, is assessed in the present paper by means of CBC analysis. Modelling demand-oriented future health-care services can possibly improve policy decisions with regard to the livelihoods and vulnerability of the rural poor.

Rural health care plays a key role in stabilizing vulnerable livelihoods of poor rural households. Most households are satisfied with the current scheme;

however, it can be improved in some areas. For example, one result of the CBC analysis is that most households would be willing to make a co-payment higher than B 30 if the services were better adapted to demands, that is, if service quality improved. The true demand is more-flexible access to health-care facilities and better coverage for medication. Nevertheless, about 20 per cent of the respondents rejected this kind of health-care scheme. However, it is not clear whether those who rejected it did so because they reject the low level of quality or because they lack money to finance the co-payment. The latter interpretation would justify the populist move by the former military Government to drop the co-payment. Another issue that respondents noted is that some households receive their card only a few months before it expires; thus, it is recommended that the universal health-care eligibility card be distributed faster, and have a longer eligibility period.

The analysis of the two ethnic groups shows that the Hmong minority rejected the health-care scheme more frequently than the Northern Thai people did. Apart from any modification of the scheme, this is a good indication of the need of health-education training that is designed specifically for the needs of the Hmong people.

Not surprisingly, men and women differed in their perceptions of the relative importance of the co-payment attribute levels. Men perceived a higher utility from the co-payment of B 30 than women did. This may indicate that they prefer the "cheap" health-care scheme, even if that means a cut in service. Women appeared more willing to pay a higher price if the benefits of the health-care scheme were improved accordingly. This means that men profit much more from the policy change of simply dropping the co-payment than women do. This is particularly relevant, as dropping the co-payment will probably further deteriorate the quality of health services, because people will go to the hospital more often and further stress the already overstretched medical resources.

Seven years after its inception, the universal health-care scheme is still teetering on the verge of crisis, in which the public demand for medical services continues to rise and almost overwhelms medical personnel at State hospitals throughout the country. The abolishment of the co-payment, which appeared small enough not to impoverish households seeking a basic minimum level of acceptable health services,[13] bears the danger of aggravating the already severe problems inherent in the universal health-care scheme: continued over-utilization, lengthy waiting times and low quality of service.

[13] Within the former universal health-care scheme, the poor and, among other groups, the elderly had been exempted from the co-payment. However, there have been indications that the exemption was not always properly applied (Coronini-Cronberg and others 2007).

The objective of the Government of Thailand must be to provide equal access to health care for all citizens and keep total health spending to a reasonable level. The latter may be achieved by co-payments for health consultations in order to maintain the capitated rate to the health sector within a reasonable range. While this argumentation may suggest reintroducing the co-payment to health care in Thailand, this may not be an easy task. Any given concession is hard to take back and will always be very unpopular. Considering the stress the Government of Thailand has experienced in 2008, such an unpopular policy change is unlikely to take place.

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ANNEX

Algebraic aspects of the conjoint analysis model

The model proposed here is based on Malhotra (2004). Y denotes overall preference for the respective choice of a financial service profile (construct) under investigation. The alternative profiles are described in terms of j-levels for i-attributes. βij is the part-worth utility[a] associated with the j^{th} level of the i^{th} attributes. The part-worth utility measures the relative importance of Xij, in estimating the dependent variable. Xij is a control variable to flag either presence (Xij = 1) or absence (Xij = 0) of the j^{th} level for the i^{th} attribute. Interaction between a person's background variables and the attribute levels is represented by γjk. Similarly, Z_k is a vector of background variables (Schrieder 1996). The componential segmentation model emphasizes the interaction between service profile *X*, and the respondents' characteristics. This requires the extension of the additive model by a vector Z_k that describes the background of respondents.

$$Y = \sum_{i=1}^{n}\sum_{j=1}^{m}\beta_{ij}Xij + \sum_{i=1}^{n}\sum_{k=1}^{m}\gamma_{jk}Z_k + \varepsilon$$

Y = choice of health insurance profile

X = explanatory health-care concept variable

Z = respondent's explanatory background variable

ε = error term

X_i for i = 1 to 3: (1) price of health-care co-payment, (2) choice of health-care facility, and (3) health coverage level

The levels for each attribute are:

X_{ij} for j = 1 to 3: (1) 30 baht, (2) 60 baht, and (3) 90 baht

X_{2j} for j = 1 to 2: (1) registered hospital, (2) any hospital

X_{3j} for j = 1 to 2: (1) cover expenses only of drugs in the National List of Essential Drugs, (2) cover expenses of drugs outside the national drug list.

[a] Part-worth utility is the contributed portion of various attribute levels to the overall preference, utility perceived (Green and Srinivasan, 1978).

Calculating the relative importance of the different attributes

$$RI_i = \left[\frac{\text{Utility Range}}{\sum \text{Utility Range } \forall \text{ attributes}} \right] \text{ x } 100,$$

where RI_i is the relative importance for the i^{th} attribute.

FACTOR PRODUCTIVITY AND EFFICIENCY OF THE VIETNAMESE ECONOMY IN TRANSITION

*Nguyen Khac Minh and Giang Thanh Long**

The purpose of this paper is to estimate changes in productivity, technical efficiency and technology across the economic sectors during the period 1985-2006. We also seek to identify the turning points for productivity growth to see whether it was accompanied by technological change and/or technical efficiency. For estimating economic growth, aggregate production function is used. We find that, during the study period, technical progress contributed about 19.7 per cent to the country's economic growth. We also estimate total factor productivity for the whole economy as well as for individual economic sectors, and the results show that the economy's productivity growth was largely driven by the industrial sector.

I. INTRODUCTION

Since the initiation of *doi moi* (renovation) programmes in 1986, the Vietnamese economy has recorded remarkable growth, in which real per capita gross domestic product (GDP) increased by 2.2 times during 1992-2005 (Phan and Ramstetter 2006). The different growth rates of economic sectors have led to a rapid transformation in the production structure of the economy. The overall high growth rate resulted mainly from the development of the industrial and service sectors, as the contribution of the agricultural sector dropped from 35 per cent of GDP in 1985 down to about 20 per cent in 2006 (Nguyen 2007).

It would be interesting to find out what parts factor inputs and technical changes played in generating such remarkable growth and how economic sectors contributed to the country's economic growth. Many challenges, such as poor infrastructure, lack of information and the large number of labourers who are

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unskilled, could have negatively affected the productive efficiency. Due to these hurdles, total factor productivity (TFP) and the technical efficiency level, particularly in terms of labour, were still low (Nguyen and Giang 2007; Nguyen, Giang and Bach 2007).

Many factors determine the size of economic growth or output at different levels (country, industry or firm), and changes in these factors cause the output to change. An analysis based on the concept of production function can explain the relationship between factor inputs and outputs. Of the factors that have potential impacts on the supply side, TFP is widely regarded as one of the most crucial. The contribution of TFP is always estimated as residual, and is usually interpreted as contributions of technical progress and/or efficiency improvement. TFP growth can be analysed and estimated through a production function (see, for example, Nadiri 1970; Jorgenson, Gollop and Fraumeni 1987; and Jorgenson 1988). Such a technical change presents a shift in the production function over time, reflecting a greater level of efficiency in combining factor inputs.

In the growth accounting approach, which uses the assumption of profit maximization, the growth of output is explained without any assumption of production function form. In this approach, the output elasticity with respect to each input is not observable and must be estimated from production function using the share of observable factor income. As such, the output growth in a given period can be explained by the growth of each input weighted by its income share. The remaining residual is known as TFP. This approach is quite popular, and has been used in many countries at different levels (see, for instance, Tinakorn and Sussangkarn 1998 for Thailand; Tran, Nguyen and Chu 2005 for Viet Nam).

Nguyen (2004) also pursued similar research objectives, using the aggregate production functions for the whole Vietnamese economy during the period 1985-2004. The paper showed that the productivity growth was largely driven by the industrial sector, and that technical progress was one of the most critical factors contributing to the economic growth. In the study period, the TFP of the country increased by about 1.5 per cent. The average GDP growth rate was 6.7 per cent, in which about 0.7 per cent (or 10.4 per cent of the growth rate) was attributable to technological progress, and 0.9 per cent (or about 13.4 per cent of the growth rate) was attributable to efficiency change. The contributions of the factor inputs (capital and labour) to the average annual GDP growth of 6.7 per cent during the study period were about 50.4 per cent and 29.2 per cent, respectively.

A problem common to the previous studies on the Vietnamese economy is that they implicitly consider the economy and its sectors to operate at efficient

levels. In practice, however, such levels cannot be achieved due to various reasons, such as the inability of labourers to adapt to new technology. Therefore, in this paper, we will overcome such a problem by providing a more detailed analysis on economic growth, production efficiency and TFP growth for the Vietnamese economy and its sectors, using macroeconomic data from the period 1985-2006 under the framework of stochastic frontier production function. We will also provide some policy suggestions for improving growth and efficiency performances.

Our paper is organized as follows. Section II provides an overview about growth performance and policy reforms in Viet Nam since *doi moi*. The theoretical framework will be discussed in section III, while the data are delineated in section IV. In section V we discuss our analysis of the estimated results. Finally, concluding remarks with a few policy implications are presented in section VI.

II. GROWTH PERFORMANCE AND POLICY REFORMS SINCE DOI MOI

In this section, we review the growth performance of the economy of Viet Nam at different times during the period 1985-2006. In addition, we will discuss some major indicators of factor productivity, including labour productivity and investment efficiency.

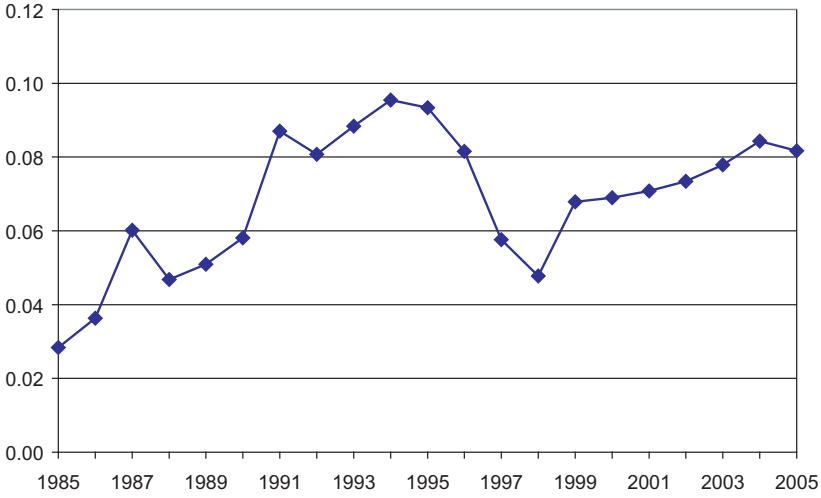
Growth performance, 1985-2006

In the early 1980s, the Vietnamese economy faced many hardships, resulting from changes in international conditions and rising weaknesses inside the economy. Particularly, Viet Nam no longer received external aid from the former socialist countries. The hybrid economic model (a combination of a centrally planned economy and a market economy), and the failures due to hyperinflation caused by price, wage and money reforms forced the Government to launch doi moi policy programmes in 1986 in order to move further towards a market economy. Since then, the economy has demonstrated impressive growth performance (figure 1).

The trends (figure 2) and growth rates (figure 3) for real GDP, real GDP per capita income, population, employment and labour productivity are illustrated below. Since 1998, the growth rates of real GDP, real GDP per capita and employment have accelerated.[1] Therefore, real GDP per capita grew more rapidly than labour

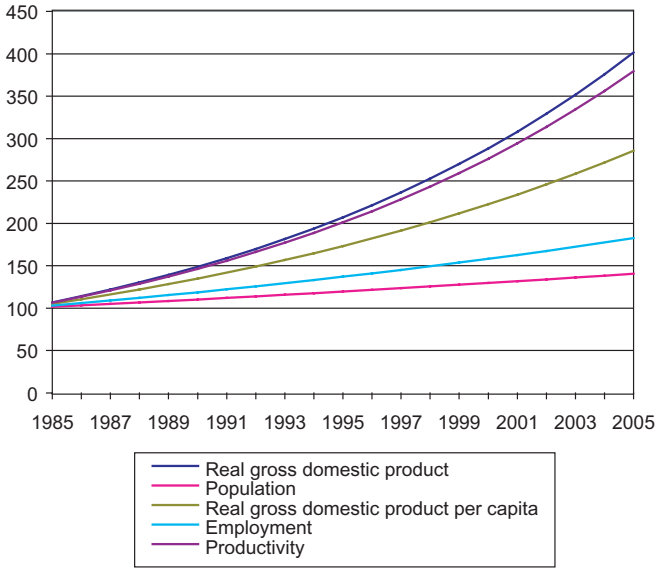
[1] The annual average growth rates between 1988 and 2005, represented by the five lines in figure 3, are as follows: real GDP (6.8 per cent); population (1.6 per cent); employment (2.9 per cent); real GDP per capita (3.8 per cent); and labour productivity (2.5 per cent).

Figure 1. Gross domestic product growth of Viet Nam (1985-2005)



Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

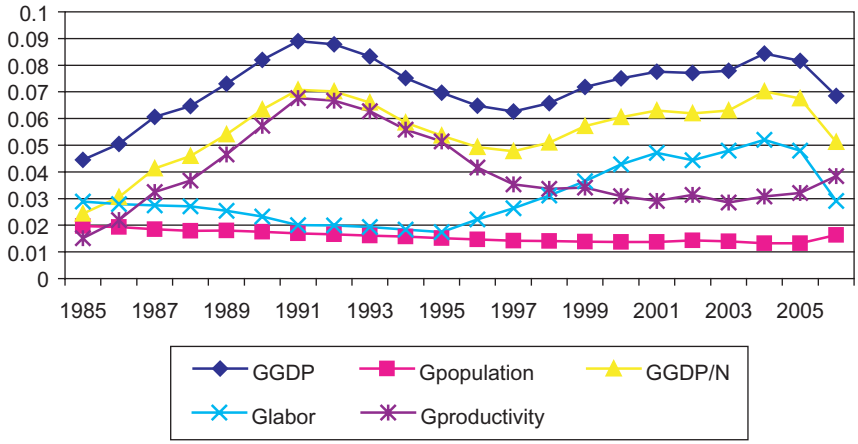
Figure 2. Long-term trends of selected economic indicators (1985-2005)



Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

Note: Long-term trends are expressed in index points, starting with a base of 1985 = 100.

Figure 3. Five-year moving average of growth rates of selected economic indicators: 1985-2006



Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

Abbreviations: GGDP, gross domestic product growth; Gpopulation, population growth; GGDP/N, per capita gross domestic product growth; Glabor, employment growth; Gproductivity, productivity growth.

productivity (real GDP per worker); this reflects employment growth during the last two decades.

While long-term growth rates are important to our understanding of economic growth in the post-*doi moi* period, we also need to evaluate these growth rates within the study period. In our analysis, we will review policy changes and other important factors that created fluctuations (upward and downward trends) in economic growth over four subperiods in Viet Nam, as presented in figure 1. The four subperiods are as follows: 1985-1988; 1989-1996; 1997-1999; and 2000-2006.

Policy reforms, 1985-2006*

1985-1988: Initial adjustments towards a market economy

In this period, the initial adjustments created new economic incentives for the economy in general and the household economy in particular. Some of the major reforms included abolishment of internal checkpoints for free movements of

* Unless otherwise indicated, information in the present section is from Tran, Nguyen and Chu (2005).

goods; adjustment of prices towards unofficial levels and reduction of rationing, in which the Vietnamese dong was evaluated in line with parallel market rates; the approval of the Land Law and recognition of long-term land-use rights; and the establishment of a two-tier banking system.

The launch of the economic renovation helped boost the economy's growth rate, which had steadily increased to 6 per cent by 1988, up from 2.8 per cent in 1986. In 1988, the growth rate of the economy reached 6 per cent. Implementation of the renovation policy clearly promoted the economy, helping end a persistent economic crisis. The positive trend of GDP growth also strengthened the willingness of the Government to engage in further reforms.

1989-1996: Early transformation to the market mechanism

This subperiod started with liberalization and stabilization packages, including the elimination of most price controls; the unification of the exchange rate system; the imposition of positive real interest rates; the issuance of the Ordinance on Economic Contracts; and the removal of subsidies to State-owned enterprises.

The radical changes in 1989 marked the turning point towards a market economy. The initial drop in the 1989 growth rate reflected the contraction of the State sector, which was due to the restructuring of State-owned enterprises. However, this drop was compensated for by strong growth in the non-State sector, which resulted from liberalization policies. The share and growth rates of the State sector in 1989 were 41 per cent and 1.8 per cent, respectively, while those of the non-State sector were 69 per cent and 9.8 per cent (Viet Nam 2003).

After 1989, the economy was on a high growth track that peaked in 1995. Fast growth in this phase could be attributable to the effects of past and ongoing reforms. Major reforms included, among others, the issuance and amendment of laws relating to Government budgets, State and non-State enterprises, credit and banking, and domestic and foreign investments; and the expansion of trade and financial relations with the international community through negotiations and further liberalization. Of particular note, Viet Nam joined the Association of South-East Asian Nations (ASEAN) and the ASEAN Free Trade Area in 1995. In addition, since the donor conference held within the Paris Club framework in 1993, the official development assistance resources associated with conditionality have helped promote structural adjustments.

In summary, this early phase of transformation laid out a fundamental framework for a market economy in Viet Nam.

1997-1999: Transformation in the context of the Asian crisis

The third subperiod brought the first major challenge to the new market economy in Viet Nam. The Asian financial crisis, which originated in Thailand and expanded to other East Asian countries, led to trade and investment disruptions. The Vietnamese economy was not directly hit by this crisis, thanks to strong capital controls. However, the reduction in foreign direct investment and the intensified competition in export markets were real blows to the economy. The growth rate declined sharply in this phase, from 8.2 per cent in 1997 down to 5.8 per cent and 4.8 per cent in 1998 and 1999, respectively (CIEM 2001).

Faced with the negative impacts of the crisis, major investors affected in Viet Nam had to solve problems in their own countries. As a result, foreign direct investment in Viet Nam decreased dramatically in terms of the number of projects and total value. Many projects were dissolved and new ones were seriously affected by foreign trade. The major importers of Viet Nam goods in East Asia had to reduce the volume of imports. The devaluation of currencies in the region further eroded the competitiveness of Viet Nam. Consequently, there was a significant fall in the export growth rate, from 28.8 per cent in 1996 down to 11.4 per cent in 1997, and to only 7.8 per cent in 1998 (CIEM 2001).

Facing such an unfavourable situation, the Government of Viet Nam devalued the currency by four times and carried out other structural reforms during the period 1997-1999. However, the external conditions affected the economy significantly through both direct and indirect channels, and thus the downward trend in GDP was observed.

2000-2006: Resumed and further growth

With the financial crisis over, the economy resumed growth momentum in 2000. After laying out the fundamental framework in the previous subperiod, the reform agenda had been turning to structural reforms, including the promotion of the non-State sector, and equitization of State-owned enterprises.

The new Enterprise Law, which was enacted in 2000 to facilitate business activities and create a more level playing field for private enterprises, helped promote the private sector. The number of newly established enterprises, mostly private, increased rapidly.

Although the equitization of State-owned enterprises began in the first subperiod, the process was extremely slow. Major frictions included the unwillingness of management boards to support equitization, difficulties in evaluating

firm value, and unequal treatments in the marketplace. The high profile of equitization in the period 2000-2006 was a positive sign of radical change in the production structure.

In short, in the period 1985-2006, Viet Nam presented an impressive average growth path, with several spurts of high growth resulting from the radical economic reforms. Strong growth in GDP brought about important conditions for raising the standard of living of the Vietnamese people. However, the high growth path can be maintained in the long run only if growth is based on increased productivity rather than on accumulation of resources. The quality of economic growth, including structural evolution and input productivity, is a key to further successes.

III. THEORETICAL FRAMEWORK

Growth and factor decomposition of growth

In the present paper, we will examine the process of growth with the aggregate production function. The aggregate production function can be used to determine the contributions of labour, capital, and technical change to economic growth. Disembodied technical change, or simply technical change, is a shift in the production function over time, which reflects greater efficiency in combining inputs. Such technical change can be estimated from the following production function:

$$Y = f(K, L, t) \text{ or } y(t) = f(K(t), L(t), t), \quad (1)$$

where t indicates time.

The change in output over time is given as follows:

$$\frac{dy}{dt} = \frac{\partial f}{\partial K}\frac{dK}{dt} + \frac{\partial f}{\partial L}\frac{dL}{dt} + \frac{\partial f}{\partial t}. \quad (2)$$

The first two terms on the right-hand side of equation (2) indicate that output change is due to increases in capital (K) and labour (L), respectively. In other words, it shows a movement along the production function. The last term on the right-hand side of equation (2) indicates that output change (or a shift in production function) is due to technical change. This type of technical change is called “disembodied” as it is not embodied in the factor inputs; rather, it involves a reorganization of inputs. It can occur with or without increases in inputs. By dividing both sides of equation (2) by output y, we can convert to proportionate rates of change and yield:

$$\frac{1}{y}\frac{dy}{dt} = \left(\frac{K}{y}\frac{\partial f}{\partial K}\right)\frac{1}{K}\frac{dK}{dt} + \left(\frac{L}{y}\frac{\partial f}{\partial L}\right)\frac{1}{L}\frac{dL}{dt} + \frac{1}{y}\frac{\partial f}{\partial t}, \quad (3)$$

where all terms are expressed as proportionate rates of changes. The first two terms on the right-hand side of equation (3) are the proportionate rates of change of two inputs (K and L, respectively), and are weighted by the elasticities of output with respect to input. The third term of equation (3) represents the proportionate rate of technical change.

If we assume that the proportionate rate of change of technical change is constant at the rate *m*, equation (3) implies that:

$$\frac{1}{y}\frac{dy}{dt} = \left(\frac{K}{y}\frac{\partial f}{\partial K}\right)\frac{1}{K}\frac{dK}{dt} + \left(\frac{L}{y}\frac{\partial f}{\partial L}\right)\frac{1}{L}\frac{dL}{dt} + m, \quad (4)$$

where *m* is the rate of neutral technical change.

The assumption of constant elasticities shows a Cobb-Douglas-type production function, and thus equation (4) can be derived from such a production function with the scale parameter *A* that increases exponentially over time, i.e. $y = \left(Ae^{mt}\right)L^{\alpha}K^{\beta}$.

Taking logarithms and rearranging the equations, we yield:

$$m = \frac{1}{y}\frac{dy}{dt} - \beta\frac{1}{K}\frac{dK}{dt} - \alpha\frac{1}{L}\frac{dL}{dt}. \quad (5)$$

In the case of a constant elasticity of substitution (CES) production function, we have:

$$y = \left(Ae^{mt}\right)\left[\delta L^{-\rho} + (1-\delta)K^{-\rho}\right]^{-h/\rho}. \quad (6)$$

Expanding *Lny* in Taylor's series approximation of the CES around $\rho = 0$, we have:

$$Lny = a + h\delta LnL + h(1-\delta)LnK + \frac{\rho h\rho(1-\delta)}{2}(LnL - Lnk)^2 + mt. \quad (7)$$

The elasticities of output with respect to labour (β_L) and capital (β_K) are presented as follows:

$$\beta_L = \frac{\partial f(.)}{\partial L}\frac{L}{f(.)} = \frac{h}{\left[1 + \frac{\delta}{1-\delta}\left(\frac{K}{L}\right)^{-\rho}\right]}, \quad (8)$$

and

$$\beta_K = \frac{\partial f(.)}{\partial K}\frac{K}{f(.)} = \frac{h}{\left[1 + \frac{\delta}{1-\delta}\left(\frac{K}{L}\right)^{\rho}\right]}. \quad (9)$$

The Malmquist productivity indices

In the present paper, we estimate productivity change as the geometric mean of two Malmquist productivity indices. Our Malmquist index is consequently a primal index of productivity change. To define the output-based Malmquist index of productivity change, we assume that for each time period t (t=1,...,T), the production technology H is presented as follows:

$$H = [(x, y): \ x \text{ can produce } y]. \quad (10)$$

We also assume that H satisfies certain axioms, which are to define meaningful output distance functions. Following Shephard (1970) or Färe (1988), the output distance function is defined at period t as:

$$inf\{\gamma(x, y/\gamma) \in H\} = (sup\{\gamma(x, \gamma y) \in H\})^{-1}. \quad (11)$$

This function is defined as the reciprocal of the maximum proportional expansion of the output vector y, given inputs x. It characterizes the technology fully, if and only if $(x, y) \in H$. In Farell's (1957) terminology, this is known as technical efficiency.

Also note that, under the assumption of constant returns to scale, the feasible maximum level of output is achieved when the productivity average value, y/x, is maximized. For simplicity, in the case of one output and one input, this level is also the maximum observed total factor average product (or productivity). In empirical studies, the maximum values represent the best practice or the highest observable productivity in the sample of countries. This best practice can be

estimated using programming techniques, which will be explained further in the next section.

By definition, the distance function is homogeneous of degree one in output. Additionally, it is the reciprocal of Farrell's (1957) measurement of output technical efficiency, which calculates how far an observation is from the frontier. To define the Malmquist index, we must describe the distance functions with respect to two different time periods, as follows:

$$inf\ \{\gamma(x^{t+1},\ y^{t+1}/\gamma) \in H\}. \tag{12}$$

This distance function measures the maximal proportional change in outputs required to make $(x^{t+1},\ y^{t+1})$ feasible in relation to the technology at period t. Note that production $(x^{t+1},\ y^{t+1})$ occurs outside the set of feasible production in period t. The value of distance function evaluates $(x^{t+1},\ y^{t+1})$ relative to technology in period t can be greater or smaller than unity. Similarly, one may define a distance function as one that measures the maximal proportional change in output required to make $(x^t,\ y^t)$ feasible in relation to the technology at period $(t+1)$.

The Malmquist productivity index can be defined as follows:

$$M_0^t = \frac{D_0^t(x^{t+1},\ y^{t+1})}{D_0^t(x^t,\ y^t)}. \tag{13}$$

In this formula, technology in period t is the reference technology. Alternatively, one could define a period, for example $(t+1)$, based on the Malmquist index as follows:

$$M_1^t = \frac{D_0^{t+1}(x^{t+1},\ y^{t+1})}{D_1^{t+1}(x^t,\ y^t)}. \tag{14}$$

In order to avoid choosing an arbitrary benchmark, we specify the output-based Malmquist productivity change index as the geometric mean of two-type Malmquist productivity indexes, as follows:

$$M_0\ (x^{t+1},\ y^{t+1},\ x^t,\ y^t)$$

$$= \left[\left(\frac{D_0^t(x^{t+1},\ y^{t+1})}{D_0^t(x^t,\ y^t)}\right)\left(\frac{D_1^{t+1}(x^{t+1},\ y^{t+1})}{D_1^{t+1}(x^t,\ y^t)}\right)\right]^{1/2}. \tag{15}$$

The output-based Malmquist productivity change index is considered as the geometric mean of (13) and (14), and it is decomposed as follows:

$$M_0\,(x^{t+1}, y^{t+1}, x^t, y^t)$$

$$= \left(\frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_1^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_1^{t+1}(x^t, y^t)}\right)\right]^{1/2}, \tag{16}$$

where the ratio outside the square bracket measures the change in relative efficiency between years t and (t+1). The geometric mean of two ratios inside the square bracket captures the shift in technology between the two periods evaluated at x^t and x^{t+1}, that is:

$$\text{efficiency change} = \frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}. \tag{17}$$

$$\text{technical change} = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_1^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_1^{t+1}(x^t, y^t)}\right)\right]^{1/2}. \tag{18}$$

Note that if $x = x^{t+1}$ and $y = y^{t+1}$, the sign of the productivity index in (16) does not change, i.e. M_0 (.) = 1. In this case, the components measuring eficiency change and technical change are reciprocals, but not necessarily equal to unity.

Improvement in productivity is associated with Malmquist indices greater than unity, while deterioration in performance over time yields a Malmquist index less than unity. Even though the components of product of efficiency change and technical change, by definition, must be equal to the Malmquist index, those components may be moving in opposite directions.

To sum up, we define productivity growth as the product of efficiency change and technical change. We interpret our components of productivity growth as follows: improvements in the efficiency change component are considered as evidence of catching up (to the frontier), while improvements in the technical change component are considered as evidence of innovation.

We believe that these approaches complement each other for productivity measurement. They also provide a natural way to measure the phenomenon of catching up. The technological progress component of TFP growth captures the shifts in the frontier of technology, or innovation. The decomposition of TFP growth into catching-up and technical change is therefore useful in distinguishing between diffusion of technology and innovation, respectively.

Stochastic frontier production function

A stochastic production frontier can be written as follows:

$$y_{it} = f(X_{it};\beta_i) + \varepsilon_t, \quad (19)$$

where t indicates time; y_{it} is output for the i^{th} economic sector at time t; X_{it} is a vector of inputs at time t; β_i is a vector of respective parameters for inputs; and ε_{it} is the composite error term.

Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) defined ε_{it} as follows:

$$\varepsilon_{it} = v_{it} - u_{it}, \quad (20)$$

where v_{it} is assumed to be independently and identically distributed $N(0, \sigma_v^2)$ random error and independent of the μ_{it}, and μ_{it} is a non-negative random variable which is assumed to be independently and identically distributed and truncated (at zero) of the normal distribution with mean μ and variance σ_μ^2 ($|N(\mu, \sigma_\mu^2|$). In this equation, μ_{it} represents technical inefficiency in production.

In the case of panel data, following Battese and Coelli (1992), the technical inefficiency (u_{it}) is defined as $u_{it} = \eta_t\, u_i \exp[-\mu(t-T)]$,t $\in \tau$ (i), where the unknown parameter η represents the rate of change in technical inefficiency over time, and tells us whether technical inefficiency is time-varying or time-invariant. For instance, a value of η that is significantly different from zero indicates time-varying inefficiency. The parameter μ determines whether the distribution of the inefficiency effects, will be either a half-normal distribution or a truncated normal distribution. For example, if $\mu = 0$, the inefficiency effects follow half-normal distribution.

The maximum likelihood estimation of equation (19) provides estimators for β and variance parameters $\sigma^2 = \sigma_v^2 + \sigma_u^2$. In addition, the variance parameter $\gamma = \sigma_u^2 / \sigma^2$ shows how technical inefficiency influences the production variances of the whole economy as well as individual sectors.

From equation (19) and (20), we get:

$$\hat{y}_{it} = y_{it} - v_{it} = f(X_{it};\, \beta_i)\, u_{it}, \quad (21)$$

where $\hat{y}_{it}$ is the observed output of the i^{th} sector at time t, and adjusted for the stochastic noise captured by v_{it}.

In our empirical analysis, we will choose one of the two following production functions.

In Cobb-Douglas form, we have:

$$LnGDP_t = \alpha_0 + \alpha_1 LnL_t + \alpha_2 LnK_t + v_t - u_t, \quad (22)$$

while in the CES form, we have:

$$LnGDP_t = \alpha_0 + \alpha_1 LnL_t + \alpha_2 LnK_t + \beta (LnK_t - LnL_t)^2 + v_t - u_t, \quad (23)$$

where subscript *t* denotes time, *GDP* is output; *K* is capital; *L* is number of labourers; αs and β are parameters to be estimated; and *v* and *u* are error terms defined previously.

If $\beta = 0$, equation (23) converts to equation (22), meaning that production function will follow Cobb-Douglas form. Otherwise, production function will follow CES form. We will examine β to choose the most appropriate production function from these two forms.

IV. DATA DESCRIPTIONS

In our paper, we will use aggregate data for the whole Vietnamese economy, as well as for individual sectors in the period 1985-2006. All the data were compiled from volumes of the *Statistical Yearbook* published by the General Statistics Office of Viet Nam (1990-2007).

Table 1 presents growth estimates for GDP, capital (*K*), labour (*L*), and capital-labour ratio (*K*/*L*) over the aforementioned subperiods. On average, the growth rate of capital was relatively stable and high, at about 8 to 16 per cent, while that of labour was low, at about 2 to 4 per cent. In addition, the estimates for *K*/*L*, which indicates the extent to which labour was equipped in the production

Table 1. Growth rates of gross domestic product, capital and labour, 1985-2006

Period	*Gross domestic product growth (percentage)*	*Capital growth (percentage)*	*Labour growth (percentage)*	*Capital-labour ratio (K/L)*
1985-1988	4.2	10.9	2.5	0.63
1989-1996	7.5	16.0	2.4	1.05
1997-1999	6.2	8.1	2.1	1.93
2000-2006	7.5	10.9	4.0	2.61
1985-2006	6.8	12.5	2.9	1.55

Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

process, show that the labour-intensive production characteristic of the 1980s slowly moved towards the more capital-intensive production observed in the 2000s.

V. ANALYSIS OF FINDINGS

Economic growth and factor decomposition of growth

To choose an appropriate production function for Viet Nam during the study period, which in turn helps us to estimate economic growth and factor growth, we tested the hypothesis that the CES and Cobb-Douglas production functions are the same. Our estimates (details are not shown here) showed that the statistic of the likelihood ratio test for equations (22) and (23) is 4.91, which is larger than the critical value (3.84). Therefore, we rejected the hypothesis that CES is the same as the Cobb-Douglas production function, and chose CES production function for our estimation.

The estimated results for the CES production function are shown in table 2. They indicate that the output elasticity of labour for the economy (0.906) is higher than the output elasticity of capital (0.240). In other words, during the past two decades, the Vietnamese economy relied more heavily on labour than capital in production processes. The estimated coefficients for the CES production function for the whole study period are shown in table 3.

Table 2. Estimated constant elasticity of substitution production function

Variable	*Coefficient*	*Standard error*	*t-statistic*	*Probability*
LnK	0.240	0.058	4.129	0.0007
LnL	0.906	0.053	16.961	0.0000
$(LnK - LnL)^2$	0.067	0.035	1.942	0.0689
t	0.013	0.006	2.074	0.0536
R-squared	0.999			
Adjusted R-squared	0.998			
Durbin-Watson statistic	1.577			

Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

Note: The dependent variable is the natural logarithm of real gross domestic product. All coefficients are significant at the 5 per cent significance level, except the coefficient of $(LnK - LnL)^2$.

Table 3. Estimated coefficients for constant elasticity of substitution production function
$GDP = A[\delta L^{-p} + (1-) K^{-p}]^{-h/p}$

Coefficient	*Value*
Efficiency (*A*)	1.0000
Distribution (δ)	0.7908
Substitution (ρ)	0.7118
Elasticity of substitution (η)	0.5842
Degree of homogeneity (*H*)	1.1462

Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

Table 4 provides further estimates of GDP growth rate, output elasticity of labour, output elasticity of capital, and return to scale of the whole economy under CES production function. It is again shown that the output elasticity of labour (β_L) was substantially higher than the output elasticity of capital (β_K) in all subperiods, meaning that the Vietnamese economy was heavily dependent on labour in production. In the study period, the average return to scale for the economy was 1.237.

Table 4. Sources of growth of the Vietnamese economy, by subperiod

Year	$\dot{GDP}$	*K/L*	β_K	β_L	*Return to scale*
1986-1988	4.2	0.6273	0.1828	0.8370	1.020
1989-1996	7.5	1.0475	0.2407	0.8997	1.140
1997-1999	6.2	1.9280	0.3402	0.9830	1.323
2000-2006	7.5	2.6082	0.3929	1.0101	1.403
1985-2006	6.8	1.5527	0.2974	0.9394	1.237

Source: Authors' estimates using data compiled from Viet Nam (1990-2007).

Note: $\dot{GDP}$ is GDP growth rate (percentage); *K/L* is capital-labour ratio; and β_L and β_K are elasticities of output with respect to labour and capital, respectively.

Table 5 shows our estimates for the growth-factor decomposition, in which all entries are expressed as a percentage of GDP growth. Factors leading to output changes in the Vietnamese economy are identified using the estimated CES production function for the whole study period (1985-2006). The aggregated production function method provides a quantitative explanation for the sources of output changes from the supply side in a certain period. The contributions of capital, labour and TFP (technical change) to economic growth in Viet Nam during

Table 5. Sources of economic growth, 1985-2006

Gross domestic product growth	Contributions of capital, labour, and total factor productivity to gross domestic product growth (percentage)		
	Capital	Labour	Total factor productivity
100	45.8	34.5	19.7

Source: Authors' estimates based on data collected from Viet Nam (1990-2007).

1985-2006 were 45.8 per cent, 34.5 per cent and 19.7 per cent, respectively. Therefore, the increase in capital stock was the biggest contributor, while TFP was the smallest.

Estimates of the whole economy and individual sectors

To estimate the efficiency of the whole economy and individual sectors, we had to determine whether the Cobb-Douglas or the CES production function form was the most appropriate, given the available data. The maximum-likelihood estimates of the parameters for the production function were obtained by using the FRONTIER Version 4.1 computer programme (Coelli 1996).

Table 6 presents the test results of various null hypotheses. The null hypotheses are tested using likelihood ratio tests. The likelihood-ratio statistic is, $\lambda = -2[L(H_0) - L(H_1)]$, where $L(H_0)$ and $L(H_1)$ are the values of the log-likelihood function under the specifications of the null hypothesis (H_0) and the alternative hypothesis (H_1), respectively. If the null hypothesis is true, then λ is approximately a chi-square (or a mixed chi-square) distribution with degrees of freedom equal to the number of restrictions. If the null hypothesis includes $\gamma = 0$, then the asymptotic distribution is a mixed chi-square distribution.

Table 6. Hypothesis tests

Null hypothesis	Log-likelihood function	Test statistic (λ)	Critical value (λ_c)	Decision
1. $H_0 : \beta = 0$	4.818	5.202	3.84	Reject H_0
2. $H_0 : \mu = 0$	7.416	1.532	3.84	Do not reject H_0
3. $H_0 : \eta = 0$	7.416	134.628	3.84	Reject H_0
4. $H_0 : \mu = \eta = \gamma = 0$	-13.223	175.906	10.50	Reject H_0

Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

Note: The critical value for the test involving $\gamma = 0$ is obtained from table 1 in Kodde and Palm (1986).

The first null hypothesis—that the production function followed the Cobb-Douglas form (or H_0: $\beta = 0$)—is rejected. Thus, the Cobb-Douglas form was not an adequate specification for the production function with the available data. In contrast, the CES form was appropriate to evaluate efficiency and productivity for the whole Vietnamese economy and its economic sectors in the study period.

The second null hypothesis, that is, that there were no technical inefficiency effects (or H_0: $\mu = 0$), is not rejected. Thus, the CES production function with $\mu = 0$ could be used for analysis.

The third null hypothesis, that is, that technical inefficiency was time-invariant (or H_0: $\eta = 0$), is also rejected at the 1 per cent significance level. This implies that technical inefficiency was not time-invariant.

The fourth null hypothesis—that there were no technical inefficiencies (or H_0: $\gamma = \mu = \eta = 0$)—is rejected at the 1 per cent significance level. This means there were technical inefficiencies during the study period.

In addition, all the estimates of γ are statistically significant at the 5 per cent significance level, and the estimates of η are all positive and statistically significant. This means technical inefficiencies were reduced during the study period. In other words, technical efficiency was improved.

Table 7 presents the estimated coefficients for the CES production function. Two indices indicate whether the economy had high production efficiency: a random error term (σ_v^2) and a technical inefficiency term (σ_u^2). Their total (σ^2) represents the total variance of output. In table 7, we can see that σ^2 (0.0552) is not particularly large, meaning that there were only small changes in total production in Viet Nam during the past decade.

The estimated technical efficiency of the whole economy under the CES production function and the frequency distributions are summarized in table 8. The mean technical efficiency for the whole country during the study period was 72.0 per cent. There were two years in which technical efficiency values were within a range of 50 to 60 per cent, with a mean of 58 per cent. There were five years in which technical efficiency values were between 80 and 90 per cent, with a mean of 82.5 per cent.

The frequency distributions of technical efficiency for three sectors are summarized in table 9. The results in table 9 are striking, as the mean technical efficiency for the services sector (97.8 per cent) was much higher than that of the agricultural sector and the industrial sector (67.9 per cent and 50.4 per cent, respectively).

Table 7. Estimated constant elasticity of substitution frontier production function

$$LnGDP = \alpha_0 + \alpha_1 LnL + \alpha_2 LnK + \beta (LnK - LnL)^2 + V - U$$

Coefficient	*Value*	*Standard error*	*t-statistic*
α_0	7.2458	0.2732	26.5200
α_1	0.3122	0.0155	20.1874
α_2	0.1309	0.0246	5.3114
β	0.0504	0.0126	4.0017
σ^2	0.0552	0.0378	1.4590
γ	0.9156	0.0613	14.9466
μ	0		
η	0.0642	0.0060	10.7582
Log likelihood function	74.7389		

Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

Notes: The dependent variable is the natural logarithm of real gross domestic product. All coefficients for capital, labour and the square of (ln*K*-ln*L*) are statistically significant at the 1 per cent significance level.

Table 8. Technical efficiency of the whole economy, 1985-2006

Efficiency range (percentage)	*Mean (percentage)*	*Standard deviation*	*Observations*
[50, 60)	58.0	1.1	2
[60, 70)	64.9	3.3	7
[70, 80)	75.3	3.0	8
[80, 90)	82.5	1.5	5
All	72.0	8.5	22

Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

Table 9. Efficiency distribution of the three sectors, 1985-2006

	Agriculture	*Industry*	*Services*
Mean (percentage)	67.9	50.4	97.8
Highest (percentage)	82.9	71.1	99.0
Lowest (percentage)	48.6	26.9	96.1
Number of observations	22	22	22

Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

The efficiency distribution also shows that the agricultural sector and the industrial sector both had a wider efficiency range than did the services sector. Specifically, the lowest technical efficiency levels for the agricultural sector and the industrial sector were 48.6 per cent and 26.9 per cent, while the highest values were 82.9 per cent and 71.2 per cent, respectively.

Decomposition of total factor productivity growth into four subperiods

The economy's TFP growth can be decomposed into four subperiods. In table 10, we present the average changes of the Malmquist productivity indices, their components, and the level of technical efficiency for each sector over the study period.

Two TFP components, namely, technical efficiency and technological progress, are analytically distinct, and they may have quite different policy implications. Therefore, there is a need to investigate the relationship between these terms for the purpose of policymaking. TFP growth should be divided into technical efficiency improvement (or the catching-up process) and technological change in order to identify the sources of productivity variation.

Technical efficiency can be defined as the ability of an industry to produce as much output as possible, given a certain level of inputs and certain technology. The three sectors considered in the present paper demonstrate purely technical efficiency and scale efficiency. High rates of technological progress could coexist with low technical efficiency performance. The fact that there was growth in technical change and decline in technical efficiency suggests that increased TFP in all economic sectors in Viet Nam during the study period might be derived from technological innovation rather than from improvements in technical efficiency. Decline in technical efficiency was partially due to decline in purely technical efficiency. Furthermore, technological change in the form of innovation (which raised productivity) obviously led to a shift of the production frontier. Therefore, the high technological change component of TFP growth associated with the low rate of technical efficiency in Viet Nam might be due to the fact that new technology could not be utilized in the best way as a result of inadaptability, low-skilled workers or mismanagement.

There are several ways to explain the deterioration in technical efficiency in the agricultural sector during the periods 1985-1988, 1989-1996 and 2000-2006. For example, the rapid growth of the industrial sector attracted more labourers, particularly those who were young, dynamic and educated. A movement of the labour force to more attractive industries caused a downward shift of supply in the labour market for the less attractive industries, which in turn made it difficult for

Table 10. Summary of mean Malmquist index of the three sectors and the whole economy

	effch	*techch*	*pech*	*sech*	*tfpch*
1985-1988					
Agriculture	1.259	0.834	1.026	1.227	1.049
Industry	1.040	1.035	1.000	1.040	1.077
Service	1.000	0.928	1.000	1.000	0.928
1989-1996					
Agriculture	1.000	0.978	1.000	1.000	0.978
Industry	1.07	1.034	1.000	1.07	1.106
Service	1.000	0.946	1.000	1.000	0.946
1997-1999					
Agriculture	1.000	1.045	1.000	1.000	1.045
Industry	1.000	1.041	1.000	1.000	1.041
Service	1.000	0.964	1.000	1.000	0.964
2000-2006					
Agriculture	1.000	0.998	1.000	1.000	0.998
Industry	1.000	1.012	1.000	1.000	1.012
Service	1.000	0.958	1.000	1.000	0.958
1985-2006					
Agriculture	1.033	0.981	1.004	1.030	1.014
Industry	1.028	1.030	1.000	1.028	1.059
Service	1.000	0.951	1.000	1.000	0.951
Country	1.020	0.987	1.001	1.019	1.007

Source: Authors' estimates based on data compiled from Viet Nam (1990-2007).

Abbreviations: effch, efficiency change; techch, technological change; pech, pure technical efficiency change; sech, scale efficiency change; tfpch, total factor productivity change.

these industries to improve performance efficiency within given factor inputs. The deterioration might also be partly due to the various strategies of each firm or group of firms in each sector. Moreover, high technical change associated with low technical efficiency could be attributable to mismanagement, the unfamiliarity of workers with new technology or other reasons.

TFP growth: a comparison of Viet Nam and regional economies

Over the last two decades, economists have seen sparks of interest in studies on TFP in many economies, including in the four "Asian Tigers" (Hong Kong, China; Republic of Korea; Singapore; and Taiwan Province of China), and

the newly industrialized economies in Asia (Indonesia, Malaysia and Thailand). This interest in TFP is a product of attempts to understand what lies behind the spectacular growth of those economies in their miracle era.

Table 11. Studies on total factor productivity growth of Viet Nam and regional economies

Author(s)	*Economy*	*Period of estimation*	*TFPG (percentage)*	*Contribution to growth (percentage)*	*Methodology and data set*
Young (1995)	Hong Kong, China	1966-1990	2.3	..	Growth accounting
Sarel (1997)	Indonesia	1978-1996	1.16	..	Growth accounting
Sarel (1997)	Malaysia	1978-1996	2.00	..	Growth accounting
Sarel (1997)	Philippines	1978-1996	-0.78	..	Growth accounting
Young (1995)	Singapore	1966-1990	0.2	..	Growth accounting
Young (1995)	Republic of Korea	1966-1990	1.7	..	Growth accounting
Young (1995)	Taiwan Province of China	1966-1990	2.6	..	Growth accounting
Ikemoto (1986)	Thailand	1970-1980	1.4	19.7	Non-parametric; growth accounting; time series
Martin (1996)	Thailand	1970-1990	1.6	42.5	Parametric; panel data
Collins and Bosworth (1997)	Thailand	1960-1994	1.8	36.0	Parametric; panel data
Sarel (1997)	Thailand	1978-1996 1991-1996	2.03	39.0	Elasticity estimation; growth accounting; panel data
Nguyen (2004)[a]	Viet Nam	1985-2004	1.56	23.39	CES production function
Nguyen (2005)[a]	Viet Nam	1986-2002	2.38	34.99	CES production function
Nguyen (2007)[a]	Viet Nam	1986-2002	0.2		Malmquist index

Sources: Studies summarized in Tinakorn and Sussangkarn (1998), unless otherwise indicated.

Abbreviations: TFPG, total factor productivity growth; CES, constant elasticity of substitution.

[a] Authors' summary.

Table 11 presents a summary of methodologies, data sets, and study periods for TFP growth (TFPG) in different countries. It is obvious that these studies find different rates of TFPG for the countries in their studies due to various reasons. An important conclusion is that different data sets, methodologies and sizes of elasticities of output to inputs may result in significantly different estimates of TFPG. Chen (1997) correctly pointed out that technical change as a residual was quite sensitive to the ways that data were measured and the time period that was chosen. In the case of Viet Nam, we find that TFPG, which is measured by different approaches, was positive during the study period (1985-2006). This is an encouraging result in comparison with the negative numbers found in some other countries. However, from the annual TFPG figures, we also could observe declines in the rate of TFPG in some subperiods in comparison with other subperiods. This occurred despite the high growth of GDP during the same period, and indicates that we should explore more factors that could influence TFPG.

VI. CONCLUDING REMARKS

The paper examined the sources of growth in Viet Nam during the period 1985-2006 using various approaches. We found that the economy's TFP growth was largely driven by capital (45.8 per cent) and labour (34.5 per cent), and partly driven by technological progress (19.7 per cent). Furthermore, using the Malmquist index at the sectoral level, we found that the productivity growth rates of the industrial sector, the agricultural sector, and the services sector were 6.3 per cent, 1.6 per cent, and -4.7 per cent, respectively. These diverse rates of productivity growth might be explained by a variety of factors, including quality of labour, namely, the composition of labourers by educational level in each sector. That the services sector had lower productivity growth than the industrial and agricultural sectors was confirmed by other methodologies used in the paper. In analyses at both the national and sectoral levels, the estimated results showed that the industrial sector contributed significantly more to the output growth and TFP growth than did the other sectors during the study period.

Low technical efficiency could be attributable to various sources, such as the inability of workers to adapt to new technology, or mismanagement in business activities. Based on our findings, it is suggested that Viet Nam improve quality of education and training, factors that are always important in improving the quality of the labour force.

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RESULTS OF SURVEYS AMONG DRIVERS AND CUSTOMERS OF FOR-HIRE THREE-WHEELERS IN FIVE SMALL TOWNS IN SRI LANKA

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Ownership of three-wheelers, a mode of paratransit, is rapidly increasing in Sri Lanka. Results of a survey among drivers and customers of for-hire three-wheelers are analysed in the present paper, which has direct policy relevance for policymakers and urban planners in Asian developing countries.

Two sets of questionnaires were employed to examine the characteristics and perceptions of for-hire three-wheeler drivers and customers. Ability to own (affordability) and flexible employment conditions emerged as the top reasons for the rapid increase. The emergence of three-wheeler services is largely attributable to inadequate public transport services in small towns. Users report that a three-wheeler reduces travel time, increases comfort, makes it easy to reach the destination, facilitates day-to-day activities, and serves well in an emergency situation.

However, the results reveal, among other things, that about 35.8 per cent of the drivers had had an accident in the 12-month period prior to the survey, 56 per cent had less than two years of driving experience, and 92.8 per cent had driven under the influence of alcohol. During the day, the most serious problems are the non-allocation of a stand or a lack of parking in crowded areas, and frequent attacks by gangsters. At night, problems include inadequate street lights and being called on for use in unlawful activities. Nevertheless, considering the employment it generates and the valuable services it provides, this industry continues to grow and operate in Sri Lanka, especially in small towns.

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I. INTRODUCTION

A variety of paratransit modes are in operation in South Asian countries. In Sri Lanka, the "three-wheeler" is one of the key paratransit modes; similar modes are used in Bangkok (the tuk-tuk) and in India (the Bajaj). The emergence of these paratransit modes in rural areas and small towns in the developing world is largely attributable to the lack of conventional public transportation facilities.

Until the late 1970s, non-motorized vehicles (such as carts) and small cars (such as the Morris Minor) were the popular paratransit modes in Sri Lanka. In 1977, the Government began allowing the import of second-hand vehicles. As a result, second-hand and reconditioned vehicles were imported, mostly from Japan, and second-hand cars and dual-purpose vehicles (for example, the Toyota HiAce) took the place of former modes. However, the prices of those vehicles were well above the limit of the majority of households in small towns. There, three-wheelers, which were introduced to the market in 1978, slowly began to capture a larger portion of public transport demand.

In recent years, ownership of three-wheelers has been increasing rapidly in Sri Lanka. According to the Department of Motor Traffic, at the end of 2005 three-wheelers accounted for 254,193 of the total 2,527,380 vehicles; motorcycles accounted for half of all vehicles (1,265,514) (Sri Lanka 2006). In 2004, 213,108 three-wheelers were in operation, meaning there were 41,085 new registrations in 2005. Of the 300,522 new registrations of vehicles in 2006, 156,626 were motorcycles and 64,466 were three-wheelers. It is interesting to note that, as in other Asian developing countries, motorcycle ownership is also increasing. However, motorcycle transport is not yet used as a for-hire mode in Sri Lanka.

At the time of writing, the price of a new three-wheeler was about $2,500,[1] and the waiting time to receive a new three-wheeler after full payment was about four weeks. Because three-wheelers have been available in Sri Lanka for 30 years, various price options exist. According to informal consultations with drivers, used or repaired three-wheelers are available at prices as low as one sixth of the cost of a new one. This broader range of affordability is a factor in their popularity.

The three-wheeler's physical characteristics, such as its smaller size, which makes it possible to fit into smaller parking spaces, are also factors in the decision of many households or individuals to invest in such a vehicle. One survey shows that 14.4 per cent of the households in the towns considered in the present study own at least one three-wheeler (table 1). Ownership of a three-wheeler at the

[1] $1 = 108 Sri Lanka rupees in June, 2008.

household level not only creates an employment opportunity for a member of the family, it increases the family status. As a result, even households with limited or reasonable capital in small towns tap the opportunity of owning a three-wheeler. The vast majority of these three-wheelers are available for passenger hire. A few are used for personal use or by companies to transport goods; those usually display a "Not for Hire" sign.

Table 1. Structure of vehicle ownership in small towns, by town
(Percentage of households)

Vehicle	*All*	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Bicycle	69.2	70	88	66	65	57
Motorcycle	61.2	57	50	67	54	78
Three-wheeler	14.4	25	10	12	9	16
Van	13.4	28	16	7	6	10
Car	10.6	18	17	9	6	3
Other	18.2	22	23	8	5	33

Source: Kumari, Rupasinghe and Siriwardana (2005).

As shown in table 1, the vehicles available at the household level in this study are categorized as bicycles, motorcycles, three-wheelers, vans, cars or other. The "other" category includes tractors, lorries, buses, land masters (vehicles used for farming activities, but seldom used for transporting people except for during harvest or festival seasons) and similar motorized vehicles.

The figures given in table 1 on the availability of various modes of travel indicate that in small towns and rural areas, passengers have few options in terms of hiring transport. Three-wheelers have been meeting more and more of the market demand formerly satisfied by other modes of complementary transportation. During the past three decades, there have been a number of different travel options, but none has been able to completely satisfy demand. Three-wheeler transportation, however, has demonstrated a capacity to handle increased demand.

With the major expansion of the three-wheeler transport industry, in 2002 an organization for drivers was formed in Colombo, namely, the All Island Three Wheeler Drivers Welfare Association. This association has branches in a few districts. According to its website (www.3wheellanka.com), one of the association's tasks is to help improve the social status of the three-wheeler drivers, many of whom feel socially oppressed. This perception affects their morale and work. The short-term objectives of the association include: (a) providing a standard uniform; (b) arranging insurance cover for drivers; (c) introducing identification stickers for

the three-wheelers; (d) and addressing similar matters which may improve the welfare of the drivers and build the general public's confidence in such transport. Despite the issues faced, the three-wheeler industry is rapidly growing. Therefore, the main objective of the present paper is simply to provide a snapshot of driver and user characteristics that could be used for future policy development.

II. LITERATURE REVIEW

Fouracre and Maunder (1979) and Jacobs, Maunder and Fouracre (1986) conducted similar studies on public transport sectors in developing countries, and cited several important reasons for the existence of paratransit systems in these countries. The top three reasons were: (a) high growth rate of demand; (b) demand diversity; and (c) low budget allocation by the Government to the conventional public transport sector. As stated by Jacobs, Maunder and Fouracre (1986), conventional public transport services, which move large numbers of travellers in most cities in developing countries, are unable to meet demand. This has given rise to paratransit or intermediate public transport modes, such as minibuses, rickshaws, shared taxis and even horse-drawn vehicles.

A study by de Silva, Nellihala and Fernando (2001) on the pattern of accidents and injuries involving three-wheelers in Sri Lanka revealed that 30 per cent of the accidents involving three-wheelers were due to the vehicle toppling over after making a sudden turn. A handle lock limits the turning radius of a three-wheeler to a minimum of 576 cm. However, among the drivers, the practice of breaking the handle lock to increase the turning angle of the vehicle was common. By removing this device, the driver of a three-wheeler could easily sneak out from the traffic as needed, but at the cost of vehicle stability. Silva, Nellihala and Fernando (2001) further concluded that alcohol consumption was also a contributing factor in accidents, particularly at night.

The media also frequently explores the public view on three-wheelers, [2] and businesses in the Sri Lanka tourism industry often provide visitors with brief descriptions of travel by three-wheeler.[3]

[2] See, for example, "Police should discipline three-wheeler drivers", *Daily News,* 21 May 2008.

[3] See, for example, www.travelsrilanka.com/index.cfm?PAGE=902, accessed on 21 June 2008.

III. RESEARCH METHODOLOGY

Insufficient public transport services, combined with a high, diverse demand for public transport, have led to service gaps, filled by the development of paratransit services in developing countries. For this reason, several towns and cities in Sri Lanka are flooded with three-wheelers. It is important to understand the vital contributions made by three-wheeler services and the place they have in society, because future transport policies clearly need to take the availability of transport modes into account. Such an understanding will assist policymakers and help them avoid long-term problems.

In the present study, two sets of questionnaires were designed to gather information from three-wheeler drivers and users. The questionnaire was deemed to be the most suitable method to gather the information needed and the best way to include a representative situation. In the questionnaire for drivers, respondents were asked about age, marital status, dependent family members, means of vehicle ownership, license status, driving experience, typical working conditions, number of trips per day, average trip distance, level of job satisfaction, daily income and expenditures, problems faced during the day and at night, and other related issues. The questionnaire for commuters included questions on age, reason for their three-wheeler usage, trip characteristics and the type of mode used in an emergency situation; respondents were also asked for comments and observations about three-wheeler service and drivers.

Nearly ten cities in Sri Lanka have a population of more than 100,000, and nearly 70 towns have a population of between 5,000 and 100,000. Five towns were selected for data collection: Galle, Ambalangoda, Embilipitiya, Wellawaya and Polonnaruwa. The selection of these towns was based on the cross-section of the population, the cost of the survey and the feasibility of the survey team to commute from an engineering faculty in the Southern Province of Sri Lanka.

A face-to-face survey was conducted with a sample of 500 professional three-wheeler drivers—100 in each of the five towns selected. Another survey was carried out among 500 randomly selected commuters, again, 100 from each town. It should be noted that some sample data collected on commuters may include responses from customers of drivers who were interviewed. The interviews for the present study were conducted between April and August of 2004 by final-year undergraduate engineering students of the University of Ruhuna in Sri Lanka, under the supervision of their lecturers. Although a conscious effort has been made to ensure that the sample data is as representative as possible, there is no simple and feasible way to check for potential sampling biases. Therefore, the study

should be considered as exploratory; however, it may provide insight and useful information for policymakers.

IV. SURVEY RESULTS: DRIVERS

In Sri Lanka, the thriving three-wheeler industry generates employment for, among others, drivers, mechanics, service personnel and spare parts dealers. As shown in table 2, about 43.6 per cent of the three-wheelers were purchased with savings, 49.0 per cent were acquired through a loan or leasing, and 7.4 per cent were received as a gift from the new owner's relatives or friends. There are three driver categories (table 2). Results from the selected five cities show that about 71.2 per cent of the owners do their own driving, 21.4 per cent of the owners rent their three-wheeler to a driver on daily or monthly basis and 7.4 per cent of owners hire a driver.

Table 2. Means of ownership and categories of drivers, by town
(Percentage of respondents)

	All	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Means of three-wheeler ownership						
By cash	43.6	50	34	44	53	37
By lease	33.6	34	46	22	37	29
By loan	15.4	13	11	24	6	23
By gift	7.4	3	9	10	4	11
Driver						
Owner	71.2	64	74	68	70	80
Renter	21.4	26	21	20	27	13
Hired driver	7.4	10	5	12	3	7

Analyses revealed that literacy level among drivers was high; most have earned their General Certificate of Education–Ordinary Level (O-level) (table 3). It is interesting to note that a few three-wheeler drivers in Galle and Ambalangoda held post-secondary degrees: 2 per cent in Galle and 6 per cent in Ambalangoda. Results also show that, for between 26 and 29 per cent of the drivers, employment as a three-wheeler driver was their first job opportunity after leaving their formal education (table 3).

Table 3. Driver's education and employment experience, by town
(Percentage of respondents)

	All	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Driver's education level						
< Grade 5	2.2	3	1	3	0	4
Up to O-Level	33.0	33	12	54	22	44
Pass O-Level	42.4	34	56	25	59	38
Up to A-Level	20.8	28	25	18	19	14
Post-secondary degree	1.6	2	6	0	0	0
Employment experience						
First job	27.2	29	26	26	27	28

Table 4. Daily income and expenses and the number of family members dependent on drivers in 2004, by town
(Percentage of respondents)

	All	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Daily income of a driver						
< 300 (SL Rs)	0.8	0	0	0	0	4
300-500 (SL Rs)	34.0	28	35	35	39	33
500-700 (SL Rs)	56	68	47	57	57	51
> 700 (SL Rs)	7.8	4	18	3	2	12
Did not report	1.4	0	0	5	2	0
Daily vehicle-related expenses for a driver (other than rent)						
< 100 (SL Rs)	25.0	31	6	26	48	14
100-200 (SL Rs)	66.8	61	82	72	47	72
> 200 (SL Rs)	8.2	8	12	2	5	14
Dependent family members per driver						
1	12.8	9	8	14	8	25
2-4	75.2	78	75	70	88	65
> 4	12.0	13	17	16	4	10

Abbreviations: SL Rs Sri Lanka rupees

Based on the figures in table 4, it appears that the daily income of drivers is reasonably high when compared with the wages of an average skilled labourer, such as a mason or carpenter, in the study areas. The results for average daily income and expenses show that in 2004, when the price of petrol was SL Rs 80 per litre, more than half of the drivers earned a daily income in the range of SL Rs 500 to SL Rs 700. In 2004, rent for a three-wheeler ranged from SL Rs 150 to SL Rs 250 per day. This rent is decided upon together by the owner and the driver who is hiring the vehicle, depending on the vehicle condition and other related issues, such as the portion of costs (for example, fuel) shared by the owner. In general, the minor expenses, such as air and repairing tyres, are borne by the driver. Major expenses, such as monthly servicing and new tyres, are usually borne by the owner.

About 75.2 per cent of the drivers support at least two or more family members; 12 per cent support four or more family members. A rough calculation shows that over 1.1 million people in Sri Lanka are supported by the three-wheeler industry, out of a total population of about 19.4 million (estimated for 2004) (Sri Lanka 2001). In the present random sample of 500, 211 drivers are unmarried; of those, 174 are under 30 years of age (table 5). Unless they drive a three-wheeler, unmarried males in this age group are more likely to be unemployed, make lower wages and work less desirable jobs. Many have never held any other kind of job, and will remain drivers until they find a better job or career.

Table 5. Marital status and age distribution of drivers, by town

	All	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Number of married drivers, by age						
< 21 years	8	2	1	3	0	2
21-30 years	96	14	18	23	24	17
31-45 years	104	24	22	17	23	18
46-55 years	65	13	18	14	8	12
> 55 years	16	6	2	1	5	2
Subtotal	289	59	61	58	60	51
Number of unmarried drivers, by age						
< 21 years	66	16	10	13	12	15
21-30 years	108	19	21	23	21	24
31-45 years	30	5	6	5	7	7
46-55 years	7	1	2	1	0	3
> 55 years	0	0	0	0	0	0
Subtotal	211	41	39	42	40	49

Given their numbers, it would seem that unmarried young drivers in the transport sector are involved in many of the safety and socially related issues addressed in table 6. Strikingly, about 92.8 per cent of the surveyed drivers admit to having driven under the influence of alcohol.

Table 6. Safety and social issues, by town

	All	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Drive while under the influence of alcohol (percentage)						
Always	1.2	3	3	0	0	0
Sometimes	36.6	23	56	29	31	44
Rarely	55.0	70	38	55	57	55
Never	7.2	4	3	16	12	1
Drove without valid license when they started out as a driver						
Yes *(percentage)*	24.4	13.0	28.0	34.0	15.0	32.0
Average period *(weeks)*	4.53	4.50	6.64	5.03	1.47	3.59
Standard deviation *(weeks)*	4.65	2.62	6.60	5.35	1.06	1.93
Number of respondents who had had at least one accident in one year (2003-2004)						
Fatal	9	0	5	0	3	1
Serious	46	13	6	14	3	10
Slight	64	11	17	15	3	18
Damage only	60	16	6	20	11	7
Total	179	40	34	49	20	36

Drivers in Sri Lanka must hold a valid license, although some low-powered farm vehicles can be driven without a license. Although police officers frequently check licenses, a sizeable portion of the younger population continues to drive a three-wheeler without one. According to our results, all drivers consulted held a valid license on the survey date. However, it was revealed that nearly 24.4 per cent began working as drivers without a valid license and had driven without a license for an average of 4.5 weeks, as indicated in table 6. When considering safety, about 35.8 per cent of the drivers noted that they had had at least one accident within the year prior to the survey date. Nine accidents involved fatalities: five in Ambalangoda, three in Wellawaya and one in Polonnaruwa.

One need only watch daily traffic in any city in Sri Lanka to observe the actual road behaviour of three-wheeler drivers, including violations of traffic rules

and regulations. Similar bad practices are also common among other drivers, but less so than among three-wheeler drivers. It has been reported that when three-wheeler drivers have an accident they insist upon huge compensation, even if they are at fault, and that they never admit to any kind of irresponsible driving (Wickramasinghe, "Police should discipline three-wheeler drivers", *Daily News,* May 21, 2008). Because of such attitudes, drivers are on the verge of losing—if they have not already lost—their reputation. Many of them dislike their job. In this connection, the experience and job satisfaction of drivers were examined; results are reported in table 7.

Many of the three-wheeler drivers come from either a middle- or lower-income household. Most enter this line of work once they complete school, or switch to it from a different job background. Many have very limited three-wheeler

Table 7. Experience and job satisfaction of drivers of three-wheelers, by town
(Percentage)

	All	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Experience as a driver of a three-wheeler						
1 year	23.0	33	21	17	13	31
2 years	33.0	35	35	30	33	32
3 years	18.4	5	18	26	31	12
+ 4 years	25.6	27	26	27	23	25
Would like to continue the job						
Yes	86.2	100	82	82	85	82
No	13.8	0	18	18	15	18
If yes, length of time driver would be willing to continue						
1 year	3.4	2	7	7	1	0
2 years	5.4	1	7	9	9	1
3 years	4.2	9	8	1	1	2
4 years	52.6	58	48	39	52	66
5 years	20.6	30	12	26	22	13
6 years	0	0	0	0	0	0
Job satisfaction						
Very good	0	0	0	0	0	0
Good	26.6	28	30	37	12	26
Moderate	55.2	47	47	52	74	56
Bad	18.0	25	23	11	13	18
Very bad	0.2	0	0	0	1	0

driving experience. The survey of drivers in the selected five towns shows that a few drivers have four or more years of experience, but none want to continue the job for more than five years. The job satisfaction among drivers is poor; almost 18 per cent evaluate their job as bad or very bad. From these comments it is clear that most of these three-wheeler drivers are looking forward to a better job.

About 73.1 per cent of the drivers said they had no problems when working during the day, while 69.9 per cent said they had no problems at night. However, the job presents a number of challenges and threats. Some drivers noted a lack of parking, passengers who do not pay, and muggings as the top daytime problems. At night, parking is not a problem, but not receiving payment, being hired for unlawful activities and kidnapping by gangsters were reported as major problems; a lack of street lights was also mentioned (table 8).

Table 8. Problems reported by drivers

Problem	*Percentage of drivers*	
	Day	*Night*
None	73.1	69.9
Parking	16.2	0.0
Passengers fail to pay	5.5	11.5
Being mugged	3.0	4.2
Being hired for unlawful activities	1.4	9.1
Being kidnapped by gangsters	0.2	4.2
Being arrested by police	0.6	0.6
Not enough street lights	–	0.6

Vehicle robberies and the use of three-wheelers for illegal activities increased during the last few years; killings and injuries to drivers were also reported by the media. These problems have led drivers to restrict their working areas, reduce their working hours, especially during the night, and, in some cases, have led them to switch their occupation. The drivers fear travelling with an unknown person, which may lead to more limitations on three-wheeler operation.

VI. SURVEY RESULTS: CUSTOMERS

The transportation services in suburban and rural areas are poor compared to those in urban areas; the focus in the present paper is on the contributions of three-wheeler services to neglected areas.

A three-wheeler can be hired to reach any place—even the most difficult areas, where access is narrow or limited—at any distance. Fares are negotiable, and are determined according to the distance, the route, the driver's mind-set and the user's three-wheeler hiring experience. With the fuel hikes in June 2008 (the price of gas went up to SL Rs 157 per litre), the hiring charges of a three-wheeler increased. In small towns, the minimum charge (flag drop charge, or initial distance charge) varies from SL Rs 50 to SL Rs 60. The subsequent charge per kilometre is usually about SL Rs 40. According to the All Island Three Wheeler Drivers Welfare Association website, some three-wheelers have meters, and, at the time of writing, could be hired for SL Rs 28 per kilometre in Colombo, the largest city in Sri Lanka. Fuel price is not the sole reason for such high fares in small towns; according to the survey results, more than 20 per cent of drivers are forced to pay high rents for a three-wheeler.

Under normal conditions (not an emergency), many commuters take a three-wheeler for distances ranging from 1 to 5 km (table 9). About 60.6 per cent of the trips were made by customers aged between 31 and 45 years. This indicates that the working population in small towns relies on three-wheelers for day-to-day transport.

The purposes of a three-wheeler trip also vary. They include, among others: travelling to school, the market, the nearest bus stop, railway station or hospital; shopping; visiting relatives; and transporting goods, including certain construction

Table 9. Three-wheeler trip length and age distribution of users, by town

	All (Percentage)	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Length of the most recent three-wheeler trip						
< 1 km	15.4	18	19	18	18	4
1-2 km	36.6	19	31	42	44	47
2-5 km	37.4	40	36	34	34	43
5-10 km	6.6	17	7	4	2	3
< 10 km	4.0	6	7	2	2	3
User age distribution						
< 15 years	5.2	8	8	3	2	5
15-30 years	10.0	3	16	15	8	8
31-45 years	60.6	70	56	63	42	72
46-60 years	20.6	15	18	17	40	13
> 60 years	3.6	4	2	2	8	2

materials. The top reason for choosing a three-wheeler (cited by 96 percent of respondents) is availability: a three-wheeler can be found at any time and at any place, providing an effective response to demand (table 10). About 86.2 per cent of the users reported that using three-wheelers reduced their travel time; 68.0 per cent said three-wheeler transport supported their daily activities well and made life easier; 61.6 per cent said it helped them to reach their destination easily; 54.4 per cent commented that it was more comfortable than other available options; and 53.8 per cent stated that the fare was affordable.

Table 10. Commuter perception of the service of three-wheelers, by town
(Percentage)

Advantage	*All*	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Availability	96.0	100	100	95	91	84
Easy to use in emergency	89.2	100	74	96	96	80
Reduces travel time	86.2	82	85	97	97	70
Supports daily needs well	68.0	28	72	95	95	50
Easy to reach destination	61.6	28	67	78	78	57
More comfortable	54.4	82	45	46	46	53
Affordable fare	53.8	71	63	51	45	39

About 89.2 per cent of the customers said that three-wheelers were easy to hire and use during an emergency. In the survey, passengers were also asked which transport mode they considered most effective in an emergency situation (any event which normally requires an ambulance). As shown in table 11, bicycles and three-wheelers topped the list as the most useful modes for managing such situations, but the preference for bicycles was clearly larger in less populated towns (no respondents chose the bicycle in Galle or Ambalangoda). Although motorbikes account for more than half of the vehicles in Sri Lanka, their use in an emergency is limited. A for-hire three-wheeler is the only vehicle available 24 hours a day everywhere, even in the rural areas. Most three-wheeler drivers have mobile phones, and they willingly give their phone numbers to known customers. Therefore it becomes quite easy for customers to hire a three-wheeler for an urgent trip, even from their residence. Considering the merits and positive contributions

listed by users, three-wheelers can be said to be the most important mode of for-hire transportation in small towns.

Table 11. Transport cited by respondents as most useful in an emergency, by town
(Percentage of respondents)

	All	*Galle*	*Ambalangoda*	*Embilipitiya*	*Wellawaya*	*Polonnaruwa*
Bicycle	29.4	0	0	40	54	53
Three-wheeler	29.2	45	44	34	11	12
Van	17.6	25	16	4	22	21
Car	12.2	18	16	6	9	12
Motorcycle	6.8	0	23	11	0	0
Others	4.8	12	1	5	4	2

Despite the advantages of three-wheeler transport, the public tends to have a negative view of drivers. As shown in table 12, about 25.7 per cent of the customers believe that it is always dangerous to travel with an unknown three-wheeler driver during the day; this figure rises to 54.6 per cent for night travel. About 99.8 per cent of users believe that three-wheeler driver contribute to at least some accidents, 97.2 per cent believe that drivers violate traffic rules and regulations at some point, 87.8 per cent believe that drivers, at least occasionally, are involved in unlawful activities, 82.8 per cent believe that drivers have drinking and driving habits and 90.0 per cent of the commuters said they believed that vehicles were used for illegal activities.

Table 12. User perceptions of for-hire three-wheeler drivers
(Percentage)

Perception	*Always*	*Sometimes*	*Rarely*	*Never*
Travel with drivers is dangerous during the day	25.7	33.7	23.1	17.5
Travel with drivers is dangerous at night	54.6	34.8	10.6	0
Drivers are more likely to contribute to accidents	35.0	50.4	14.4	0.2
Drivers violate traffic rules and regulations	29.8	42.6	24.8	2.8
Drivers are involved in unlawful activities	12.4	34.6	40.8	12.2
Drivers drink and drive	5.8	29.4	47.6	17.2
Drivers use vehicle for illegal activities	5.0	48.8	36.2	10.0

VI. INTERPRETATION

Three-wheeler operations began in Sri Lanka in 1978, when the Government allowed private companies to provide transport services; currently such services are found throughout the country. Even in small towns, a three-wheeler can be seen at least every few hundred metres. Hence, it is understandable that a broad segment of society considers the three-wheeler to be an essential short-haul transport option. As a result, the number of three-wheelers in Sri Lanka is rapidly increasing.

The three-wheeler transport industry provides many jobs. It is a viable employment option for many people, because renting or owning a three-wheeler is affordable, and because the service adapts easily to diverse demands. In this way, this industry helps to reduce the unemployment problem, especially for school graduates, and subsequently improves income levels and living standards of the general public. A rough computation indicates that about 12 per cent of the total population in Sri Lanka is totally dependent on this paratransit mode for their livelihoods.

Three-wheelers provide a continuous source of passenger transport during the day and at night, and fill the gaps left by the traditional means of public transport. In small towns and rural areas, purposes for the trips vary widely; among others, they include taking care of an emergency, getting to the hospital or to school, transporting materials or goods, returning home, visiting someone and getting to the bus stand or railway station. The majority of users are over 30 years old, which implies that the service is relied on most by the working population. Passengers reported that three-wheelers reduced travel time, were more comfortable than other forms of transit, and were easy to call during the day and at night. Many users reported that three-wheelers were a reliable mode of transit for an emergency situation that normally required the services of an ambulance. Therefore, it is clear that the services of three-wheelers are perceived as highly useful by many and are strongly integrated in small towns.

Despite their perceived advantages, three-wheelers and their drivers are still not respected by the public who actually use the services or by others, such as drivers of other motorized vehicles. Most of the general public seems to believe that travelling with an unknown driver can be dangerous, and that three-wheeler drivers contribute to accidents, violate rules and regulations, drink and drive, and are involved in illegal activities. If the user perceptions in the present study are true and the prevailing negative image of the three-wheeler driver reflects reality, steps must be taken at the appropriate level to rectify the situation. Drivers of three-wheelers also face difficulties, and tend not to want to continue their job for

long. The survey results showed that many have no option other than to drive a three-wheeler until they find better employment. Therefore, the difficult conditions of this industry need to be improved.

Despite these challenges, and the lack of efforts to address them, three-wheelers are still a main source of transport. In most places, drivers are likely to be seen idling in their vehicles at the unofficial stands found throughout the small towns and larger cities. However, the Government has not yet formulated a code for the three-wheeler industry or set up an appropriate regulatory institution.

I. POLICY RECOMMENDATIONS AND CONCLUSIONS

Studies have shown that there tends to be a broad correlation between certain characteristics of a city and the type of transport system developed in it. A similar correlation could be expected in Sri Lanka in the near future, due to the existence of the three-wheeler industry. The present paper highlighted a few insights related to the existence of the three-wheeler paratransit mode.

Major issues have arisen within the three-wheeler industry since it began 30 years ago. While authorities have, on several occasions, given thought to ways and means of initiating measures, so far, no concrete action has been taken. Therefore, the Government; governmental, non-governmental and research organizations; universities; the All Island Three Wheeler Drivers Welfare Association; and other stakeholders should help conduct awareness programmes to improve the status of the three-wheeler industry in the society, and subsequently to improve the social welfare of three-wheeler drivers and the general public.

In terms of addressing the current situation, some possible measures include: (a) developing legislation to prevent unauthorized alterations to the turning angle of three-wheelers; (b) arranging appropriate three-wheeler stands in small towns; (c) allocating adequate funds for improving awareness of three-wheeler drivers and their status in the society; and (d) providing educational resources and a special licensing scheme for three-wheeler drivers.

Looking ahead to the future of the three-wheeler industry in Sri Lanka, there should be actions to restrict three-wheeler operations within busy city limits, as is being done in Mumbai, India and Singapore. Therefore, it is recommended that indices as well as limits for restricting three-wheeler services in the central business district area be identified in future studies. However, considering the value three-wheeler services seem to hold, as indicated in the survey, it is likely that such transport will continue to be needed in small towns and rural areas.

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A CAUSAL RELATIONSHIP BETWEEN ENERGY CONSUMPTION AND ECONOMIC GROWTH IN NEPAL

*Kamal Raj Dhungel**

In the present paper, an attempt is made to examine the causal relationship between the per capita consumption of coal, electricity, oil and total commercial energy and the per capita real gross domestic product (GDP), using a co-integration and vector error correction model. The increase in real GDP, among other things, indicates a higher demand for a large quantity of commercial energy such as coal, oil and electricity. This implies that low infrastructure development limits the usage of commercial energy, which may also hold back economic growth. Empirical findings reveal that there is a unidirectional causality running from coal, oil and commercial energy consumption to per capita real GDP, whereas a unidirectional causality running from per capita real GDP to per capita electricity consumption is found. It is suggested that the input of per capita energy consumption stimulates enhanced economic growth in Nepal.

I. INTRODUCTION

The causal relationship between energy consumption and economic growth is a well-studied subject in economic literature. In recent years, there has been a renewed interest in examining the relationship between these variables, given the impact that energy consumption has on climate change. The higher economic growth rates pursued by developing countries are achievable only in association with the consumption of a larger quantity of commercial energy, which is a key factor of production, along with capital, labour and raw materials. Moreover, the social development that represents the demand side of energy depends on the pattern of commercial energy consumption in an economy. Accordingly, a consumer decides to consume a set of energy products that maximizes his or her utility. From this perspective, energy is seen to play a vital role in the economic and

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social development of the nation. There is still debate on whether energy consumption is a stimulating factor for, or a result of, economic growth. However, when more commercial energy, particularly oil and coal, is used to achieve projected economic growth rates, carbon dioxide (CO_2) emissions rise accordingly. The increased share of CO_2 in the atmosphere, a product of the rampant use of fossil fuels, has negative impacts on natural systems and is a main factor contributing to climate change. In this context, the consumption of coal and oil should be replaced with renewable alternatives, such as wind, solar and hydropower, that do not emit CO_2.

II. A BRIEF SURVEY OF THE LITERATURE

A number of studies have investigated the causal relationship between energy consumption and economic growth. For example, Kraft and Kraft (1978) used the methodology of Sims (1972) to assess causality between energy consumption and economic growth over the period 1947-1974. Their work explicitly proved that the causality was running from gross national product (GNP) to energy consumption in the economy of the United States of America. Aqeel and Butt (2001) studied the causal relationship between energy consumption and economic growth in Pakistan. To investigate the causal relationship among the stated variables (economic growth, electricity, etc.), they preferred to use the co-integration and Granger tests. They found unidirectional causality running from economic growth to petroleum consumption, and causality running from economic growth to gas consumption. In contrast, they found unidirectional causality running from electricity consumption to economic growth.

Cheng and Lai (1997) found causality running from gross domestic product (GDP) to energy consumption in the case of Taiwan Province of China. They used a co-integration and error correction model to investigate the causality among chosen variables. Mozumder and Marathe (2007) applied a vector error correction model to explore the dynamic Granger causality. They found that per capita GDP Granger causes per capita energy consumption in Bangladesh.

Masih and Masih (1996) considered six Asian economies to examine the temporal causality between energy consumption and income; they applied a vector error correction. Those findings show that energy consumption was causing income in India, income was causing energy consumption in Indonesia, and that a bidirectional causality existed in Pakistan. They used an ordinary vector autoregressive model for the remaining three countries (Malaysia, Philippines and Singapore). In those cases, their investigation failed to reveal any causality between energy consumption and income. Soytas and Sari (2003), in their examination of

causality, had mixed results. They found bidirectional causality in Argentina, and causality that ran from GDP to energy consumption in Italy and the Republic of Korea. In contrast, they found that the causality ran from energy consumption to GDP in France, Germany, Japan and Turkey.

Yang (2000), using updated data from 1954-1997 for Taiwan Province of China, investigated the causal relationship between GDP and the aggregate categories of energy consumption, including coal, natural gas and electricity. He found bidirectional causality between total energy consumption and GDP. Pachauri (1977) found that there was a strong correlation between economic development and energy consumption in India. Stern (2000), in a study of the United States economy, found in a multivariate dynamic analysis that energy not only Granger causes GDP, it is also significant in explaining GDP. He also found co-integration in a relationship between the factors (GDP, capital, labour and energy). Ghali and El-Sakka (2004) conducted a study on the causality between energy consumption and economic growth in Canada. They found that the short-run dynamics of variables indicate that Granger's causality between output growth and energy use was bidirectional.

Dhungel (2005) used co-integration to determine electricity demand in Nepal. The estimated income elasticity and price elasticity of electricity showed that there is a proportional change in the demand for electricity associated with changes in income and price. Abosedra and Baghestani (1989) argued that the direct Granger test should be used, and concluded that for all sample periods tested (1947-1972, 1947-1974, 1947-1979 and 1947-1987), there was a unidirectional causality between GNP and economic growth in the United States economy. Fatai, Oxley and Scrimgeour (2001) used both Granger and Toda-Yamamoto methodology to assess causality between energy consumption and economic growth over the period 1960-1999. Their work explicitly proved that causality was running from energy consumption to GDP in India, Indonesia, the Philippines and Thailand, and Granger causality was running from GDP to energy consumption in Australia and New Zealand. Cheng (1999) estimated Granger causality between energy consumption and economic growth for the period 1952-1995 by using co-integration and error correction models. He found that the Granger causality was running from GNP to energy consumption in India.

III. DATA AND ECONOMETRIC METHODOLOGY

Data and variables

Time series data on total commercial energy consumption and real GDP over the period 1980-2004 is used to investigate the causal relationship between energy consumption and economic growth. The necessary data were collected from various sources in Nepal. For example, the data for electricity consumption were collected from annual reports of the Nepal Electricity Authority (Nepal various years). Coal consumption data were collected from the Water and Energy Commission Secretariat (Nepal 1997, 2006). The data for petroleum consumption were collected from the Water and Energy Commission Secretariat and the Nepal Oil Corporation. Data on total commercial energy consumption and GDP were collected from several issues of the Economic Survey published by the Ministry of Finance (Nepal various years).

The main purpose of this article is to estimate the relationship between commercial energy consumption and economic growth in general, and attempts are made to assess the causality between total commercial energy consumption (TCEC) and real GDP. Furthermore, TCEC is decomposed into three main parts: coal, electricity and oil, facilitating the assessment of the relationships between the consumption of individual commercial energy types and real GDP.

Econometric methodology

The time series data present a number of methodological problems. It is convenient to estimate relationships through the regression method only if the series are stationary. In the context of a time series, "stationary" refers to a condition wherein the series have constant mean and constant variance. Most of the time series data reflect trend, cycle and/or seasonality. These deterministic patterns must be removed to make the series stationary. Time series that are not stationary and whose properties have not been subjected to an examination could produce invalid inferences. The coefficient determination (R^2) measures the variability in dependent variable explained by the independent variable. High value of R^2 will likely give rise to spurious regression (Granger and Newbold 1974). To examine the Granger causality between TCEC and real GDP, as well as between each of the three decomposed elements (coal, electricity and oil consumption) and real GDP, the following methodology has been adopted.

Co-integration test

Co-integration analysis and error correction models have become the standard techniques for the study of electricity demand. Engle and Granger (1987) applied both techniques to forecast electricity demand. Since 1987, subsequent developments related to this approach have relied on the use of new techniques to identify co-integrating relationships. Johansen's method is the latest improvement on the theory of co-integration as applied in long-run analysis of time series data.

The concept of co-integration has become popular in recent years. It states that if a long-run relationship exists between two variables, then the deviations from the long-run equilibrium path should be bounded. If this is the case, the variables are said to be co-integrated. For variables to be co-integrated, two conditions must be satisfied: the series for the individual variables must have the same statistical properties, and the variables must be integrated in the same order. If a series is stationary after differencing once, it is said to be integrated of order one or I(1).

When using time series data, the test of unit root is very important for determining stationarity. Stationarity tests which determine the unit root in a series are proposed by Dickey and Fuller (1981). The standard approach to test for non-stationarity of each observed time series (Y observed over T time periods (Y_t)) is to estimate an augmented Dickey Fuller (ADF) test regression, as shown below.

We consider a simple autoregressive (AR)(1) process:

$$Y_t = \rho\, Y_{t-1} + x_t\, \delta + \varepsilon_t, \tag{1}$$

where x_t represent optional regressors that may consist only of a constant, or a constant and trend; ρ and δ are parameters to be estimated; and the ε_t are assumed to be white noise. If $| \rho | \geq 1$, y is a non-stationary series and the variance increases with time and approaches infinity. If $| \rho | \geq 1$, y is a (trend-) stationary series. Thus, the hypothesis of (trend-)stationarity can be evaluated by testing whether the absolute value of ρ is strictly less than one.

The ADF test is carried out by estimating equation (1) after subtracting y_{t-1} from both sides of the equation:

$$\Delta Y_t = \alpha\, Y_{t-1} + x_t\, \delta + \varepsilon_t, \tag{2}$$

where $\alpha = \rho - 1$. The null and alternative hypotheses may be written as:

H_0: $\alpha = 0$ and H_1: $\alpha < 0$

The simple Dickey Fuller unit root test described above is valid only if the series is an AR(1) process. If the test does not provide enough basis to reject the null hypothesis, then the series are said to be level stationary. This would imply that they satisfy the condition to construct a co-integration system.

If the series are integrated of the same order, a static regression in the levels of the variables is run and tested to see if linear combinations of the variables are themselves integrated of the same order as the individual variables. If the variables are co-integrated, then there should exist a linear combination of these variables which is integrated of order one less than the individual variables. In the co-integrating regression

$$Y_t = b_0 + b_1 X_t + u_t, \quad (3)$$

if $Y \rightarrow I(n)$ and $X \rightarrow I(n)$, then Y and X are said to be co-integrated if $u_t \rightarrow I(n-1)$. In equation (3), b_1 measures the long-run relationship between Y and X, and u is the divergence from the equilibrium path. If there is a long-run relationship between Y and X, then the divergence from it should be bounded. Engle and Granger (1987) argue that if co-integration holds, then the error correction model is a valid representation of the adjustment process.

Granger causality test

The Granger (1969) approach to the question of whether X causes Y is to determine how much of the current Y can be explained by past values of Y, and then to see whether adding lagged values of X can improve the explanation. Y is said to be Granger-caused by X if X helps in the prediction of Y, or if the coefficients on the lagged Xs are statistically significant. Note that two-way causation is frequently the case: X Granger causes Y and Y Granger causes X.

It is important to note that the statement "X Granger causes Y" does not imply that Y is the effect or the result of X. Granger causality measures precedence and information content but does not of itself indicate causality in the more common use of the term.

It is better to use more rather than fewer lags in the test regressions, since the Granger approach is couched in terms of the relevance of all past information. It is necessary to pick a lag length, l, that corresponds to reasonable beliefs about the longest time over which one variable could help predict the other.

If two series are co-integrated, then a Granger causality test must be applied to determine the direction of causality between the variables under consideration.

The following equations are used to determine the causality:

$$\Delta Y_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{k} \gamma_i \Delta X_{t-i} + \mu \quad (4)$$

$$\Delta X_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta X_{t-i} + \sum_{i=1}^{k} \psi_i \Delta Y_{t-i} + \mu \quad (5)$$

where Y_t and X_t are defined as Y and X observed over t time periods; Δ is the difference operator; k represents the number of lags; α, β, ψ and γ are parameters to be estimated; and μ represents the serially uncorrelated error terms. The test is based on the following hypotheses:

H_0: $\gamma_i = \psi_i = 0$ for all i's

H_1: $\gamma_i \neq 0$ and $\psi_i \neq 0$ for at least some i's.

At this point, it is necessary to examine the criteria for causality. The hypothesis would be tested by using t-statistics. If the values of the γ_i coefficient are statistically significant but those of the ψ_i are not, then X causes Y ($X \rightarrow Y$). On the contrary, if the values of the ψ_i coefficients are statistically significant but those of the γ_i coefficients are not, then Y causes X ($Y \rightarrow X$). If both γ_i and ψ_i are significant then there exists bidirectional causality between X and Y ($X \rightarrow Y$).

IV. EMPIRICAL FINDINGS

Unit root test

The ADF test was used in most of the studies of the present paper to examine the unit root in the set of five series comprising the relationships between coal consumption, electricity consumption, oil consumption and TCEC and real GDP. In the level form the ADF test supports the hypothesis that all five series under consideration are non-stationary. However, in the first difference all become stationary. The ADF test for the data of first difference indicates that the five series under consideration are all of order I(1). However, the GDP variable is second difference stationary, or I(2). The ADF coefficients in the level and first difference are reported in table 1.

Co-integration test

The empirical findings of Johansen co-integration tests (table 2) reveal that both the Eigen and Trace tests indicate the existence of a consistently co-integrating vector or long-run equilibrium relation among variables during the sample period of 1980-2004. When the values of the test were estimated, linear

Table 1. Empirical results of a unit root test

Variable	Augmented Dickey Fuller statistics			
	Level	Probability	First difference	Probability
lnCC	-2.0544057	0.5412	-6.9540081*	0.0001
lnEC	-1.436815	0.8228	-7.783153*	0.0000
lnOC	-0.938054	0.9344	-5.298443*	0.0015
lnTCEC	-2.894120	0.1815	-6.212976*	0.0002
lnGDP	0.966159	0.9997	-9.696064*	0.0000

Source: Nepal various years a; Nepal various years b; Nepal 1997, 2006.

Abbreviations: ln, natural logarithm; CC, per capita coal consumption; EC, per capita electricity consumption; OC, per capita oil consumption; TCEC, per capita total commercial energy consumption; GDP, per capita gross domestic product (millions of Nepalese rupees)

* The Mackinnon values for the rejection of a hypothesis of a unit root test at 1, 5 and 10 per cent are -3.75, -2.99 and -2.64, respectively.

deterministic trend was assumed. The lag interval in first differences is three. The trace test indicates that there are three and two co-integrating equations at the 5 and 1 per cent levels, respectively. Moreover, the maximum Eigen value test indicates three co-integrating equations at both the 5 and 1 per cent levels.

More specifically, table 2 shows that at the 5 per cent level of significance the likelihood ratios (trace statistics) for the null hypothesis having no (r = 0), one (r = 1) or two (r = 2) co-integrations (171.77, 81.23 and 35.65) are higher than the critical values (76.07, 54.46 and 34.91). The likelihood ratios of having three and four co-integrating relationships (6.80 and 0.23) are less than the critical values (20.04 and 6.65).

Table 2. Unrestricted co-integration rank test

Null hypothesis (H_0)	*Alternative hypothesis* (H_1)	*Maximum Eigen value statistics*	*Trace statistics*	*95 per cent critical value (Eigen)*	*95 per cent critical value (Trace)*
r = 0	r = 1	90.53	171.77	38.77	76.07
r = 1	r = 2	46.32	81.23	32.24	54.46
r = 2	r = 3	28.11	35.65	25.52	34.91
r = 3	r = 4	6.56	6.80	18.63	20.04
r = 4	r = 5	0.23	0.23	6.65	6.65

Source: Nepal various years a; Nepal various years b; Nepal 1997, 2006.

Note: The letter "r" represents the number of co-integrating equations.

At the 5 per cent level of significance, the maximum Eigen value statistics for the null hypothesis having no, one and two co-integrations (90.53, 46.32 and 28.11, respectively) are higher than the critical values (38.77, 32.24 and 25.52). The maximum Eigen value statistics of having three and four co-integrating relationships (6.56 and 0.23, respectively) are less than the critical values (18.63 and 6.65). Hence, according to likelihood ratio and maximum Eigen value statistics tests, per capita coal consumption and GDP, electricity consumption and GDP, oil consumption and GDP and TCEC and GDP series are co-integrated. Thus, a long-run equilibrium relationship between these series is co-integrated.

Granger causality test

The results of Granger causality between per capita coal consumption, electricity consumption, oil consumption and TCEC and per capita real GDP, as well as the computed F values and their respective probabilities for the data of those series during the period 1980-2004 with specific lag period, as calculated through equations (4) and (5), are presented in table 3. To assess whether the null hypothesis is to be accepted or rejected, a significance level of 5 per cent is chosen. The lag lengths were chosen by using Akaike's information criterion.

The Granger causality is found to run from per capita coal consumption to per capita real GDP. The null hypothesis of "per capita coal consumption does not

Table 3. Empirical results of a causality test

Independent variable	*Lag*	*Equation 4*[a]		*Equation 5*[b]	
		F-statistics	*Probability*	*F-statistics*	*Probability*
lnCC	2	4.35504	0.00867	–	–
lnGDP		–	–	1.29862	0.29728
lnEC	4	1.39332	0.29740	–	–
lnGDP		–	–	5.20554	0.00148
lnOC	3	9.54973	0.00090	–	–
lnGDP		–	–	2.03772	0.16175
lnTCEC	6	5.81605	0.00504	–	–
lnGDP		–	–	2.15842	0.18547

Source: Nepal various years a; Nepal various years b; Nepal 1997, 2006.

[a] $\Delta Y_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{k} \gamma_i \Delta X_{t-i} + \mu$

[b] $\Delta X_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta X_{t-i} + \sum_{i=1}^{k} \psi_i \Delta Y_{t-i} + \mu$

Abbreviations: ln, natural logarithm; CC, per capita coal consumption; EC, per capita electricity consumption; OC, per capita oil consumption; TCEC, per capita total commercial energy consumption; GDP, per capita gross domestic product (millions of Nepalese rupees)

Granger cause per capita real GDP" is rejected at the 5 per cent level of significance in equation (4), where the value of γ is 4.35504 with probability 0.00867. The null hypothesis "per capita real GDP does not Granger cause per capita coal consumption" is accepted in equation (5), where the value of ψ is 1.29862 with probability 0.29728. This indicates that per capita real GDP does not Granger cause per capita coal consumption, as the value of the test statistic is not significant even at the 10 per cent level of significance in equation (5). Both results were calculated using two lag periods.

In terms of electricity, the Granger causality is found to run from per capita real GDP to per capita electricity consumption. The null hypothesis of "per capita real GDP does not Granger cause per capita electricity consumption" is rejected at the five per cent level of significance in equation (5), where the value of ψ is 5.20554 with probability 0.00148. The null hypothesis "per capita electricity consumption does not Granger cause per capita real GDP" is accepted in equation (4), where the value of γ is 1.39332 with probability 0.29740. This indicates that per capita electricity consumption does not Granger cause per capita real GDP, as the value of the test statistic is not significant even at the 10 per cent level of significance in equation (4). Both results were calculated using four lag periods.

Turning to oil, the Granger causality is found to run from oil consumption to real GDP. The null hypothesis of "per capita oil consumption does not Granger cause per capita real GDP" is rejected at the 5 per cent level of significance in equation (4), where the value of γ is 9.54973 with probability 0.00090. The null hypothesis "per capita real GDP does not Granger cause per capita oil consumption" is accepted in equation (5), where the value of ψ is 2.03772 with probability 0.16175. This indicates that per capita real GDP does not Granger cause per capita oil consumption, as the value of the test statistic is not significant even at the 10 per cent level of significance in equation (5). Both results were calculated using three lag periods.

Most important is the assessment of the causality between per capita TCEC, which is the sum total of per capita coal, oil and electricity consumption and per capita real GDP. The empirical results show that the Granger causality is found to run from per capita TCEC to per capita real GDP. The null hypothesis of "per capita TCEC does not Granger cause per capita real GDP" is rejected at the 5 per cent level of significance in equation (4), where the value of γ is 5.81605 with probability 0.00504. The null hypothesis "per capita real GDP does not Granger cause per capita TCEC" is accepted in equation (5) where the value of ψ is 2.15842 with probability 0.18547. This indicates that per capita real GDP does not Granger cause per capita TCEC, as the value of the test statistics is not significant even at

the 10 per cent level of significance in equation (5). Both results were calculated using six lag periods.

V. SUMMARY, POLICY IMPLICATIONS AND CONCLUSIONS

The economic development of Nepal is extremely low—less than 4 per cent during the period under consideration. The actual economic growth rate is much lower than the target rates set by the Government through its fiscal policies. If the targets are to be translated into action, the country must develop its capacity to adequately manage the supply of commercial energy.

Empirical findings reveal that there is a unidirectional causality running from coal, oil and commercial energy consumption to per capita real GDP, whereas a unidirectional causality running from per capita real GDP to per capita electricity consumption is found. This suggests that per capita energy consumption is the stimulating input for enhancing economic growth in Nepal. In view of these observations, it is suggested that the Government of Nepal make a rigorous effort to encourage investment in energy generation.

Nepal possesses 42,000 MW of economic hydroelectricity potential, but fewer than 600 MW have been tapped so far. A policy of increasing investment in electricity generation should be implemented to replace the use of coal and oil in the process of enhancing economic growth in Nepal. Also needed is a policy to supplement energy such as coal and oil through energy exchange programmes with neighbouring countries. In a previous paper (Dhungel 2003), the author estimated electricity income and price elasticity from the time series data (1980-1999) and found that the income elasticity of electricity was 3.51. That estimate shows that, for the long run, Nepal does not have to arrange demand management, which in turn suggests that Nepal should accelerate investment in the generation of hydroelectricity in order to improve supply management. Likewise, the present study suggests that Nepal will need to put more effort into increasing electricity supply investment as part of a national strategy towards advanced development in the long run.

Moreover, the present study supports the argument that an increase in real income ceteris paribus leads to increases in energy consumption. As their real income increases, people tend to spend a higher proportion of their income on goods or services that consume large amounts of energy, such as private cars and motorcycles, tractors and water pumps on farms and in households, plasma televisions and high-speed Internet connections; all this contributes to an increase in industrial establishments that are energy intensive.

Thus, for developing countries like Nepal, economic growth requires energy infrastructure—particularly for electricity. A high economic growth rate will increase the consumption of commercial energy. Development of immense water-resource projects to generate electricity is one infrastructure option. However, it requires a huge investment, and the infrastructure would take a significant amount of time to construct. Thus, small and microprojects and biogas (from animal dung) are better options for providing electric energy to the people of rural areas. These options, if developed adequately, would be helpful in reducing greenhouse gas emissions by reducing the use of fossil fuel and biomass.

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