Economic Instruments and the Pollution Impact of the 2006-2010 Vietnam Socio-Economic Development Plan

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Abstract: The current study derives optimal growth paths for pollution emission charges, in order to control future water pollution emissions in the Vietnamese manufacturing sector. The study builds on a prior study, which estimated the manufacturing sector pollution impact of the 2006-2010 SEDP development plan for Vietnam (Jensen et al.; 2008). The current study demonstrates that effective implementation and moderate expansion of optimal emission charges, under certain conditions, could have been used, as part of the 2006-2010 SEDP development plan, to control pollution emissions at 2005 levels. Moreover, such a scenario would have been accompanied by a moderate expansion in fiscal revenues and a relatively minor economy-wide efficiency loss. The current study, therefore, suggests that effective implementation and gradual expansion of pollution emission charges should be incorporated into future SEDP development plans, in order to control pollution emissions as development progresses in Vietnam.

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1. Introduction

A previous study provided an assessment of the industrial pollution impact of the 2006-2010 Socio-Economic Development Plan (SEDP) for Vietnam (Jensen et al.; 2008). In particular, that study was focusing on manufacturing industries. The current study uses the results from that study, to assess the scope for pollution control, based on the effective implementation of pollution emission charges, as part of future SEDP development plans. Accordingly, the current study provides a counterfactual analysis of 'what could have been achieved' if effective implementation of optimal pollution emission charges had been undertaken as part of the current 2006-2010 SEDP development plan.

The current study will focus on deriving optimal growth paths for pollution emission charges, in order to maintain water pollution emissions, over the period 2006-2010, at 2005 levels. The current study will focus on two particular types of water pollution, including Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS). The previous study (Jensen et al.; 2008) indicated that pollution emissions are likely to grow strongly as a consequence of the strong growth rates, envisioned, in the 2006-2010 SEDP plan. Maintaining future water pollution emissions at 2005 levels, therefore, implies emission reductions for BOD and TSS pollutants of around 58-60% in 2010. The purpose of this study is three-fold:

- Analyze the necessary price incentives (emission charge increases) for producer's to undertake the necessary pollution treatment,
- Analyze the economy-wide efficiency loss (real GDP reduction) from optimal changes to emission charges, and
- Analyze the fiscal implications of the optimal changes to emission charges.

The current study relies on a Computable General Equilibrium (CGE) model of the 1-2-3 type (Devarajan, Lewis & Robinson; 1990). Specifically, the current study relies on the so-called 'standard model' with marketing margins (Arndt, Jensen, Robinson & Tarp, 2000; Lofgren, Harris & Robinson, 2002). In order to address the above questions, the standard model is turned into a dynamically recursive CGE model, and modified to account for the producer's pollution treatment problem. Optimality conditions for cost minimization are explicitly derived and implemented within the standard model, and separate specifications are derived based on the assumption of

- A fixed *semi-elasticity* of the pollution emission rate with respect to the variable pollution treatment cost rate, and
- A fixed *elasticity* of the pollution emission rate with respect to the variable pollution treatment cost rate.

The two CGE model specifications lead to different qualitative results. Separate analyses of pollution emission charges are, therefore, undertaken for each of the two model specifications. Questions, which were asking for necessary information to estimate the semi-elasticities and full elasticities, were included in a recent Small- and Medium-sized Enterprise (SME) survey (Rand et al.; 2008). Unfortunately, little information was obtained. One single company provided the necessary information. Based on this single observation, semi-elasticities for BOD and TSS emissions could be derived.[1] However, no full elasticity estimates could be derived. In any case, due to the uncertainty surrounding available information, the current study includes an extensive set of sensitivity analyses, in order to investigate the sensitivity of conclusions to changes in the parameterization of the models.

Section 2 will present the CGE model framework, including the optimality conditions for the solution of the producer's pollution treatment problem (section 2.1), the basic specification of the Vietnam CGE model (section 2.2), and the structure of the Vietnamese economy (section 2.3). Section 3 will present the analyses of the optimal levels and growth paths for pollution emission charges, economy-wide costs due to efficiency losses, and the fiscal implications of increasing emission charges. Separate analyses will be presented for fixed semi-elasticities resp. fixed elasticities of the pollution emission rate with respect to the variable pollution treatment cost rate in sections 3.1 resp. 3.2. Conclusions are offered in section 4.

2. Pollution treatment costs and emission charges

2.1. Semi-elasticity vs. Elasticity

The current study is focusing on the producer's pollution treatment problem. Producers are facing a trade-off between costs from

- Pollution Emission Charges, and
- Pollution Treatment Costs.

The producer faces a trade-off, since pollution emissions – and, hence, the payment of pollution emission charges – may be reduced through an increase in treatment costs. Essentially, this argument suggests that there is an inverse relationship between the share of production revenues devoted to pollution treatment – the pollution treatment cost rate (vap) – and the pollution intensity of production revenues – the pollution emission coefficient (cp).[2] This relationship may

[1] A semi-elasticity for Chemical Oxygen Demand (COD) emissions could also be derived. However, since emission coefficients for COD emissions are unavailable, COD emission growth paths were not calculated in the previous study (Jensen et al.; 2008). COD emission charges were, therefore, not included in the current study.

[2] The unit of the pollution treatment cost rate (vap) is percent, while the unit of the pollution emission coefficient (cp) is kg/Mio. VND. See Appendix A for further discussion of the producer's pollution treatment problem.

be specified on the basis of a fixed semi-elasticity or a fixed elasticity. Based on the existence of a fixed semi-elasticity between cp and vap, the functional relationship becomes

(1) $$ln(cp) = -a1 * vap,$$

while, based on the existence of a fixed elasticity between cp and vap, the functional relationship becomes

(2) $$ln(cp) = -a2 * \ln(vap)$$

Under the assumption of a fixed semi-elasticity of the pollution emission coefficient with respect to the pollution treatment cost rate (equation 1), the producer's pollution treatment problem becomes (see appendix A for details):

(OPT 1)
$$Min_{vap}\ tp * cp * \sum_{t=1}^{T} X_t + ivp * \sum_{t=1}^{T} X_t + vap * \sum_{t=1}^{T} X_t$$
$$s.t. \quad ivp = b * vap$$
$$ln(cp) = -a1 * vap$$

In the solution of the minimization problems, the government chooses tp to provide price incentives for the producer to undertake pollution treatment, while the producer chooses vap to minimize total pollution emission charges and treatment costs. The basic optimization problem includes both an investment pollution treatment cost rate (ivp) and a variable pollution treatment cost rate (vap). In what follows, investment costs will be disregarded (b=0). Based on these assumptions, the optimal level of the variable pollution treatment cost rate (vap*), and the implied optimal level of the pollution emission coefficient (cp*), may be expressed as functions of the emission charge rate (tp):

(VAP 1) $$vap^*(tp) \approx \frac{1}{a1} \ln(a1 * tp)$$

(CP 1) $$cp^*(tp) \approx \frac{1}{a1 * tp}$$

Optimality conditions for the solution of the producer's pollution treatment problem, under the assumption of a fixed elasticity of the pollution emission coefficient with respect to the pollution treatment cost rate (equation 1), may be derived in a similar way. In this case, the producer's pollution treatment problem becomes (see appendix A for details):

(OPT 2)
$$Min_{vap}\ tp * cp * \sum_{t=1}^{T} X_t + ivp * \sum_{t=1}^{T} X_t + vap * \sum_{t=1}^{T} X_t$$
$$s.t. \quad ivp = b * vap$$
$$ln(cp) = -a2 * \ln(c * vap)$$

Moreover, the optimal level of the variable pollution treatment cost rate (vap*), and the implied optimal level of the pollution emission coefficient (cp*), can be derived as functions of the emission charge rate (tp):

(VAP 2) $$vap^*(tp) \approx c^{1/(1+a2)} * [a2 * tp]^{1/(1+a2)}$$

(CP 2) $$cp^*(tp) \approx c^{1/(1+a2)} * [a2 * tp]^{-a2/(1+a2)}$$

Equations (VAP 1) and (CP 1) will form the basis for the implementation of the producer's pollution treatment problem, based on a fixed 'semi-elasticity, while equations (VAP 2) and (CP 2) will form the basis for the implementation of the producer's pollution treatment problem, based on a fixed 'elasticity of the pollution emission coefficient (cp) with respect to the variable pollution treatment cost rate (vap)'.

2.2. CGE model Specification

The current analyses are based on the Computable General Equilibrium (CGE) modeling methodology. A multi-sector CGE model of the 1-2-3 model type with marketing margins, as first described in Arndt, Jensen, Robinson & Tarp (2000) and later documented in Löfgren, Harris & Robinson (2002), is applied to demonstrate how effective implementation of pollution emission charges may be used to control the expansion of pollution, which accompanies the Vietnam SEDP development plans.

The so-called 'standard model' is a static model. For the measurement of dynamic effects of the emission charges, the static model is transformed into a dynamically-recursive CGE model, by adding equations for updating of labor and capital factor stocks. The underlying 'standard model' is characterized by employing a constant elasticity of substitution (CES) specification for production functions, and a linear expenditure system (LES) specification for household consumption demand. On the trade side, imperfect substitution between domestic production and imports are modeled through a CES specification (the Armington assumption), while imperfect transformation of domestic production into export goods is modeled through the use of a constant elasticity of transformation (CET) specification.

The CGE model framework is calibrated on the basis of a semi-aggregate 25 sector version of the 2003 Vietnam SAM (Jensen & Tarp; 2007). The 25 sectors include:

- Sector 1: Agriculture, forestry, and fishery,
- Sectors 2-22: Manufacturing sectors,
- Sector 23: Other industry,
- Sector 24: Trade service, and
- Sector 25: Other services.

Agriculture, forestry and fishery sectors were aggregated into one sector, while service sectors were aggregated into two sectors including trade services and other services. Industrial sectors were aggregated into 22 different sectors including 21 manufacturing sectors and one other industry sector. The high level of disaggregation among manufacturing sectors reflects the focus of the current study, i.e. pollution emissions in the manufacturing sector.

The neoclassical closure of the CGE model includes fixed factor supplies and flexible relative factor prices (labor market closure), fixed real government consumption, fixed real government transfers, and flexible government savings (government budget closure), fixed non-government institutional savings rates and flexible investment (savings-driven investment closure), and fixed foreign savings inflows combined with a flexible real exchange rate (external closure). In addition, flexible relative goods prices are allowed to clear the goods market. The closure is typically referred to as "the standard neoclassical closure", since relative prices clears all markets, including markets for goods, factors and foreign exchange. While relative prices are used to clear markets, the absolute price level is not determined within the neoclassical model. The model therefore specifies the household consumer price index for marketed goods as a price numeraire.

Over time, the price numeraire is assumed to follow the GDP price deflator growth path from the 2006-2010 SEDP development plan. Updating of labor factor stocks are based on fixed growth rates, while updating of the capital factor stock is based on endogenously determined investment rates. Land (which is only used as a factor input in agricultural production) is assumed to be fixed over time. Finally, various model parameters, including total factor productivities, trade shares, and terms-of-trade, are allowed to change over time, in order to target real and nominal macro-economic growth paths from the 2006-2010 SEDP development plan (see the study by Jensen et al. (2008) for more details).

2.3. Structure of the Economy

The supply and demand structure of the Vietnam economy is displayed in Table 1. In terms of value added generation, the Vietnam economy is divided relatively equally among four economic sectors: agriculture, forestry, and fishery (23.4% of GDP), manufacturing industry (30.0% of GDP), other industry including construction, and mineral extraction (21.4% of GDP), and trade and other services (25.2% of GDP). International trade is concentrated in manufacturing goods, accounting for around 56 percent of exports and 85 percent of imports, while other industrial goods account for an additional 21 percent of exports. Furthermore, primary agricultural goods account for 8 percent of exports and 2 percent of imports, while services account for 15 percent of exports and 13 percent of imports. International trade shares, which are important determinants of trade flows in the CGE model, reflect the general trade pattern. Accordingly, trade shares are relatively high for manufacturing (exports: 34%; imports: 50%), other industry (exports: 33%), and service sectors (exports: 27%; imports: 26%), while they are relatively small for primary agriculture (exports: 17%; imports: 6%).[3]

[3] The relatively low international export share for primary agriculture may reflect that agricultural products are being processed before being exported. Accordingly, the food processing sector accounts for 12 percent of all exports, and has an international export share of 33 percent.

Table 1. Supply and Demand Structure of the Vietnam Economy (percent)						
	Value Added	Exports	Imports	E/X	M/Q	Domestic Margin Rate
Agriculture, Forestry & Fishery	23.4%	7.6%	1.8%	16.7%	5.6%	3.7%
Food products and beverages	6.0%	12.0%	3.2%	33.2%	14.8%	2.5%
Tobacco products	0.5%	0.6%	0.4%	24.3%	26.9%	3.4%
Textiles	1.3%	0.9%	8.8%	12.9%	63.7%	1.7%
Wearing appare	2.0%	12.6%	1.6%	73.8%	31.4%	4.2%
Tanning and dressing of leather	1.4%	8.6%	3.0%	69.8%	49.3%	1.4%
Wood and wood products	0.8%	3.6%	0.9%	83.1%	61.4%	5.1%
Paper and paper products	0.5%	0.4%	1.9%	11.7%	48.7%	4.4%
Publishing and printing	0.5%	0.0%	0.1%	0.8%	4.0%	5.4%
Refined petroleum products	2.0%	3.0%	9.3%	50.6%	80.9%	0.0%
Chemicals and chemical products	2.4%	0.9%	8.9%	9.6%	54.2%	4.1%
Rubber and plastics products	1.6%	1.4%	4.4%	18.7%	47.0%	3.7%
Other non-metallic mineral products	2.5%	0.9%	1.0%	6.6%	9.2%	5.7%
Basic metals	1.0%	2.7%	11.9%	41.6%	78.5%	2.4%
Fabricated metal products	0.2%	0.1%	0.3%	9.7%	36.2%	3.8%
Machinery and equipment	0.6%	2.1%	10.7%	78.0%	95.6%	1.7%
Electrical machinery and apparatus	0.7%	2.0%	4.1%	40.6%	62.8%	3.2%
Communication equipment	0.4%	1.8%	3.8%	68.8%	84.7%	1.5%
Medical and precision instruments	0.2%	0.3%	1.5%	42.0%	81.7%	3.2%
Motor vehicles, trailers and semi-trailers	2.2%	0.5%	3.9%	5.2%	35.9%	3.4%
Other transport equipment	1.4%	0.8%	3.2%	15.7%	47.9%	2.3%
Other manufacturing	1.7%	1.5%	1.9%	16.6%	24.3%	3.0%
Other Industry	21.4%	20.8%	0.5%	32.7%	1.6%	0.5%
Trade	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%
Other Services	23.4%	15.0%	12.8%	26.8%	26.2%	0.0%
Total / Average	100.0%	100.0%	100.0%	30.0%	34.3%	2.8%

Source: 2003 Vietnam SAM (Jensen & Tarp; 2007).

Note: E – Exports; M – Imports; X – Domestic Production; Q – Domestic Supply.

The underlying SAM data set included a total of six trade and transport margin accounts for imports, exports, and domestically marketed production. For the purposes of model implementation, the six trade and transport margin accounts were aggregated into three marketing margin accounts for imports, exports, and domestically marketed production. Domestic marketing margin rates are presented in Table 1, and they indicate that agricultural marketing margin rates are relatively high (3.7 percent) compared to manufacturing (3.1 percent) and other industry (0.5 percent). Service sectors do not incur marketing costs per definition. Compared to the overall average (2.8 percent), agricultural marketing margin rates are relatively high. Reductions in marketing margins (including trade and transport costs) are therefore particularly important for the development of the agricultural sector and for employment in rural areas.

Table 2. Projections of Pollution Emissions (tons/year)						
	Base year	2006	2007	2008	2009	2010
BOD	5,452	6,582	8,050	9,681	11,447	13,876
TSS	6,049	7,228	8,740	10,413	12,219	14,671

Source: Jensen et al. (2008)

Table 3. Optimal Emission Charges Rate to maintain BOD Emissions at the 2005 level as part of the 2006-2010 SEDP development plan

	2006				
Semi-elasticity[1]	8	83	830	8.3E+03	8.3E+04
Emissions (Base Run)[2]	6.58	6.58	6.58	6.58	6.58
Emission Charge Rate (100 VND/kg)	180824	18082	1808	181	18
Emissions (2005 level)[2]	5.45	5.45	5.45	5.45	5.45
Optimal Emission Charge Rate (100 VND/kg)	216404	21878	2183	218	22
Emissions change (%)	-17.2%	-17.2%	-17.2%	-17.2%	-17.2%
Emission Charge Rate change (%)	19.7%	21.0%	20.8%	20.7%	20.7%

	2010				
Semi-elasticity[1]	8	83	830	8.3E+03	8.3E+04
Emissions (Base Run)[2]	13.88	13.88	13.88	13.88	13.88
Emission Charge Rate (100 VND/kg)	180824	18082	1808	181	18
Emissions (2005 level)[2]	5.45	5.45	5.45	5.45	5.45
Optimal Emission Charge Rate (100 VND/kg)	444650	46262	4604	460	46
Emissions change (%)	-60.7%	-60.7%	-60.7%	-60.7%	-60.7%
Emission Charge Rate change (%)	145.9%	155.8%	154.6%	154.5%	154.5%

Source: Own Calculations; [1] Semi-elasticity of pollution emission coefficient with respect to treatment cost rate; [2] 1000 tons/year

Table 4. Emission Charges, Treatment Costs and Efficiency Loss to maintain BOD Emissions at the 2005 level, as part of the 2006-2010 SEDP development plan

	2006				
Semi-elasticity[1]	8	83	830	8.3E+03	8.3E+04
Emissions (Base Run)[2]	6.6	6.6	6.6	6.6	6.6
Emission Charges (bio. VND)	149,558.0	14,955.8	1,495.6	149.6	15.0
Treatment Costs (bio. VND)	0.0	0.0	0.0	0.0	0.0
GDP (bio. VND)	773,575.9	773,575.9	773,575.9	773,575.9	773,575.9
Emissions (2005 level)[2]	5.5	5.5	5.5	5.5	5.5
Optimal Emission Charges (bio. VND)	147,628.9	14,833.4	1,494.4	149.5	15.0
Treatment Costs (bio. VND)	26,517.6	2,826.0	281.8	28.2	2.8
GDP (bio. VND)	762,753.0	771,511.2	773,398.6	773,561.5	773,575.3
Emission Charges change (bio. VND)	-1929.1	-122.4	-1.2	-0.01	0.00
Treatment Costs change (bio. VND)	26517.6	2826.0	281.8	28.2	2.8
GDP change (bio. VND)	-10823.0	-2064.7	-177.3	-14.5	-0.6

	2010				
Semi-elasticity[1]	8	83	830	8.3E+03	8.3E+04
Emissions (Base Run)[2]	13.9	13.9	13.9	13.9	13.9
Emission Charges (bio. VND)	374,148.7	37,414.9	3,741.5	374.1	37.4
Treatment Costs (bio. VND)	0.0	0.0	0.0	0.0	0.0
GDP (bio. VND)	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4
Emissions (2005 level)[2]	5.5	5.5	5.5	5.5	5.5
Optimal Emission Charges (bio. VND)	341,188.5	36,375.0	3,732.1	374.1	37.4
Treatment Costs (bio. VND)	306,988.6	34,169.7	3,487.6	349.5	35.0
GDP (bio. VND)	896,150.1	1,018,281.1	1,037,084.3	1,038,727.9	1,038,864.3
Emission Charges change (bio. VND)	-32960.1	-1039.9	-9.4	-0.10	0.00
Treatment Costs change (bio. VND)	306988.6	34169.7	3487.6	349.5	35.0
GDP change (bio. VND)	-142721.3	-20590.3	-1787.1	-143.5	-7.1

Source: Own Calculations; [1] Semi-elasticity of pollution emission coefficient with respect to treatment cost rate; [2] tons/year

3. Results

This section contains analyses of the need for raising emission charges in order to control future BOD and TSS water pollution emissions. Table 2 reproduces projected growth paths for industrial pollution emissions among manufacturing sectors, based on the 2006-2010 SEDP development plan (Jensen et al.; 2008), and the projections demonstrate that BOD emission levels will increase from 5,450 tons in 2005 to 13,880 tons in 2010, while TSS emission levels will increase from 6,049 tons in 2005 to 14,671 tons in 2010 as a consequence of the 2006-2010 SEDP development plan. The analyses in this section will review the optimal changes in emission charges, which would be necessary and sufficient to control the dramatic expansion of pollution emissions. In addition, the analyses will review the economy-wide efficiency losses and fiscal implications.

Separate analyses will be based on the two approaches to the pollution treatment problem, i.e. the model which is based on a 'fixed *semi-elasticity* of the pollution emission rate with respect to the treatment cost rate', and the model which is based on a 'fixed *elasticity* of the pollution emission rate with respect to the treatment cost rate'. Simulations with a fixed semi-elasticity will be presented and analyzed in section 3.1, while simulations with a fixed elasticity will be presented and analyzed in section 3.2.

3.1. Fixed Semi-elasticity of Pollution Emission Rate

The simulations of this section are based on the assumption of a fixed *semi-elasticity* of the pollution emission rate with respect to the treatment cost rate. Accordingly, the CGE model, which is employed in this section, is extended by the twin relationships of VAP1 and CP1, which were derived from the producer's pollution treatment problem with a fixed semi-elasticity of the pollution emission rate with respect to the treatment cost rate (see section 2.1).

3.1.1. Biological Oxygen Demand (BOD)

Table 3 presents the results of the simulations of optimal pollution emission charge rates, which would have been necessary to implement (effectively) as part of the 2006-2010 SEDP plan, in order to maintain BOD emissions at the 2005 level. The optimal emission charge rates are given under the label 'optimal emission charge rate'. The results also include base run calculations of the pollution emission charge rate. These results are provided under the 'emission charge rate' label. The base run estimates of emission charge rates were derived from the model simulations, in order to ensure that current levels of BOD pollution emissions reflect the optimal choice of producers, given (i) the effective implementation of emission charge rates, and (ii) the parameter value of the semi-elasticity. The base run values should, therefore, not be interpreted as optimal.

Instead, they should be interpreted as counterfactual values, which reflect current pollution emission rates.

The sensitivity analyses in Table 3 indicate that the base run emission charge rates vary inversely with the parameter value of the 'semi-elasticity of the pollution emission rate with respect to the treatment cost rate'. The intuition behind this result is that producers increase treatment costs in response to increasing emission charges, and that the increase in the treatment costs are inversely related to the impact of treatment costs on pollution emissions, i.e. inversely related to the parameter value of the semi-elasticity. The results show that a relatively low semi-elasticity (8) is associated with a very high emission charge rate of approximately VND 18.1 Mio. VND/kg, while a relatively high semi-elasticity (8.3E4) is associated with a relatively low emission charge rate of approximately 1800 VND/kg. This analysis shows that it is crucial to obtain a proper semi-elasticity estimate in order to make an assessment of the appropriate level of emission charge rates, i.e. the level which would lead producers to choose current emission levels as their optimal response.

The single applicable observation from the SME survey (Rand et al.; 2008) indicates that a 0.041% treatment cost share (of the production value) leads to a 71% reduction in the BOD pollution emissions rate. These numbers indicate that the BOD semi-elasticity should be around 830. The results in Table 3 suggest that this is consistent with a base run emission charge rate around 181,000 VND/kg. The following conclusions emerge:

- If the observation of the semi-elasticity (830) is representative for the manufacturing sector, effective implementation of BOD emission charge rates around 181,000 VND/kg would lead producers to choose current levels of BOD pollution emissions as their optimal response.
- If the observation of the semi-elasticity (830) is representative for the manufacturing sector, effective implementation of BOD emission charge rates above 181,000 VND/kg would be required in order to reduce BOD pollution emissions below current levels.

As noted above, the BOD emission levels are estimated to increase from 5,450 tons in 2005 to 6,580 tons in 2006 and 13,880 tons in 2010 as a consequence of the 2006-2010 SEDP development plan. Table 3 provides estimates of optimal emission charge rates, which would have allowed for BOD emissions to be fixed at the 2005 level. The results indicate that the optimal yearly growth rates for emission charge rates are relatively invariant to changes in the parameter value of the semi-elasticity. Accordingly, in order to maintain 2006-2010 BOD emissions at the 2005 level, the emission charge rate would have had to increase by 20-21% in 2006 and by 146-156% in 2010, over the base run level.

Table 4 presents measures of producer costs and economy-wide efficiency losses. Producer costs include emission charges and treatment costs. The results indicate that, regardless of parameter values, the optimal increase in the emission charge rate will lead to a reduction in fiscal revenues from emission charges. Accordingly, producers will increase pollution treatment and reduce pollution emissions in order neutralize the increase in emission charge rates. However, the price of reduced pollution emissions is increasing treatment costs. The results show that the reduction in emission charge payments will, always, be dominated by a very strong relative increase in pollution treatment costs.

In the case of a semi-elasticity of 8300, the optimal emission charge rate increases from a base run value of 1800 VND/kg to 2200 VND/kg in 2006 and 4600 VND/kg in 2010. Due to increased pollution treatment, total emission charge payments drops by 10 Mio. VND in 2006 and 100 Mio. in 2010. At the same time, the threat of increased emission charge collections leads producers to increase pollution treatment costs by 28.2 Bio. VND in 2006 and 349.5 Bio. VND in 2010. It follows that total producer costs increases by around 28 Bio. in 2006 and around 349 Bio. VND in 2010.

The increased producer costs leads to an economy-wide efficiency loss in terms of a reduction in GDP. In the case of a semi-elasticity of 8300, the economy-wide efficiency loss will amount to a 143.5 Bio. VND reduction in real GDP in 2010. This amounts to around 0.014% of GDP. The following conclusions emerge from above analysis:

- The optimal level of the BOD emission charge rate varies inversely with the parameter value of the semi-elasticity,
- The optimal growth rates of the BOD emission charge rate are relatively invariant with respect to the parameter values of the semi-elasticity, and
- Under certain conditions, BOD emissions could have been controlled, as part of the 2006-2010 SEDP development plan, through effective implementation and moderate expansion of the optimal emission charge rate. Such a scenario would have been accompanied by a marginal reduction in fiscal revenues and a relatively minor economy-wide efficiency loss.

The conditions under which BOD emissions could be controlled, as part of the 2006-2010 SEDP plan, at a reasonable cost, refers to the situation where the ‘semi-elasticity of the pollution emission rate with respect to the treatment cost rate’ is greater than 5000. This condition reflects a situation where e.g. a representative medium-sized manufacturing company, with a 10 Bio. VND turnover, would achieve a 50% reduction in BOD emissions through a yearly variable pollution treatment cost of 1 Mio. VND.

Table 5. Optimal Emission Charges Rate to maintain TSS Emissions at the 2005 level as part of the 2006-2010 SEDP development plan

	2006				
Semi-elasticity[1]	13	130	1300	1.3E+04	1.3E+05
Emissions (Base Run)[2]	7.23	7.23	7.23	7.23	7.23
Emission Charge Rate (100 VND/kg)	106749	10675	1067	107	11
Emissions (2005 level)[2]	6.05	6.05	6.05	6.05	6.05
Optimal Emission Charge Rate (100 VND/kg)	126204	12764	1276	128	13
Emissions change (%)	-16.3%	-16.3%	-16.3%	-16.3%	-16.3%
Emission Charge Rate change (%)	18.2%	19.6%	19.5%	19.5%	19.5%

	2010				
Semi-elasticity[1]	13	130	1300	1.3E+04	1.3E+05
Emissions (Base Run)[2]	14.67	14.67	14.67	14.67	14.67
Emission Charge Rate (100 VND/kg)	106749	10675	1067	107	11
Emissions (2005 level)[2]	6.05	6.05	6.05	6.05	6.05
Optimal Emission Charge Rate (100 VND/kg)	247285	25898	2589	259	26
Emissions change (%)	-58.8%	-58.8%	-58.8%	-58.8%	-58.8%
Emission Charge Rate change (%)	131.6%	142.6%	142.5%	142.5%	142.5%

Source: Own Calculations; [1] Semi-elasticity of pollution emission coefficient with respect to treatment cost rate; [2] tons/year

Table 6. Emissions Charges, Treatment Costs and Efficiency Losses from maintaining TSS Emissions at the 2005 level, as part of the 2006-2010 SEDP development plan

	2006				
Semi-elasticity[1]	13	130	1300	1.3E+04	1.3E+05
Emissions (Base Run)[2]	7.2	7.2	7.2	7.2	7.2
Emission Charges (bio. VND)	98,434.2	9,843.4	984.3	98.4	9.8
Treatment Costs (bio. VND)	0.0	0.0	0.0	0.0	0.0
GDP (bio. VND)	777,885.2	963,594.1	982,165.0	984,022.1	984,207.8
Emissions (2005 level)[2]	6.0	6.0	6.0	6.0	6.0
Optimal Emission Charges (bio. VND)	97,670.9	9,793.6	983.9	98.4	9.8
Treatment Costs (bio. VND)	16,352.0	1,750.7	175.2	17.5	1.8
GDP (bio. VND)	779,743.9	963,343.6	982,129.4	984,017.9	984,207.7
Emission Charges change (bio. VND)	-763.4	-49.8	-0.5	-0.01	0.0
Treatment Costs change (bio. VND)	16352.0	1750.7	175.2	17.5	1.8
GDP change (bio. VND)	1858.7	-250.5	-35.6	-4.1	-0.1

	2010				
Semi-elasticity[1]	13	130	1300	1.3E+04	1.3E+05
Emissions (Base Run)[2]	14.7	14.7	14.7	14.7	14.7
Emission Charges (bio. VND)	246,252.5	24,625.3	2,462.5	246.3	24.6
Treatment Costs (bio. VND)	0.0	0.0	0.0	0.0	0.0
GDP (bio. VND)	1,276,812.3	1,668,023.3	1,707,144.4	1,711,056.5	1,711,447.7
Emissions (2005 level)[2]	6.0	6.0	6.0	6.0	6.0
Optimal Emission Charges (bio. VND)	233,811.9	24,208.2	2,458.7	246.2	24.6
Treatment Costs (bio. VND)	196,415.4	21,455.3	2,178.1	218.1	21.8
GDP (bio. VND)	1,283,826.3	1,661,799.3	1,706,490.8	1,710,982.7	1,711,446.2
Emission Charges change (bio. VND)	-12440.6	-417.0	-3.9	-0.04	0.0
Treatment Costs change (bio. VND)	196415.4	21455.3	2178.1	218.1	21.8
GDP change (bio. VND)	7014.0	-6224.0	-653.6	-73.8	-1.5

Source: Own Calculations; [1] Semi-elasticity of pollution emission coefficient with respect to treatment cost rate; [2] tons/year

3.1.2. Total Suspended Solids (TSS)

Table 5 presents the results of the simulations of optimal pollution emission charge rates, which would have been necessary to implement (effectively) as part of the 2006-2010 SEDP plan, in order to maintain TSS emissions at the 2005 level. Again, the optimal emission charge rates are given under the 'optimal emission charge rate' label, while the counterfactual base run emission charge rates are provided under the 'emission charge rate' label. The results confirm the results from the previous section, i.e. that base run emission charge rates vary inversely with the parameter value of the 'semi-elasticity of the pollution emission rate with respect to the treatment cost rate'.

Moreover, the results show that a relatively low semi-elasticity (13) is associated with a very high emission charge rate of VND 10.7 Mio. VND/kg, while a relatively high semi-elasticity (1.3E5) is associated with a relatively low emission charge rate of 1100 VND/kg. These results confirm that it is crucial to obtain a proper semi-elasticity estimate in order to make an assessment of the appropriate level of emission charge rates, i.e. the level which would lead producers to choose current emission levels as their optimal response.

The single applicable observation from the SME survey (Rand et al.; 2008) indicates that a 0.041% treatment cost share (of the production value) leads to a 60% reduction in the TSS pollution emission rate. These numbers indicate that the TSS semi-elasticity should be around 1,250. The results in Table 5 suggest that this is consistent with a base run emission charge rate around 107,000 VND/kg. The following conclusions emerge:

- If the observation of the semi-elasticity (1,250) is representative for the manufacturing sector, effective implementation of TSS emission charge rates around 107,000 VND/kg would lead producers to choose current levels of TSS pollution emissions as their optimal response.
- If the observation of the semi-elasticity (1,250) is representative for the manufacturing sector, effective implementation of TSS emission charge rates above 107,000 VND/kg would be required in order to reduce TSS pollution emissions below current levels.

Accordingly, the current analysis (based on a semi-elasticity of 1,250) indicates that effective implementation of emission charge rates around 107,000 VND/kg would lead producers to choose current levels of TSS pollution emissions as their optimal response. In comparison, the emission charge rate for TSS emissions was 200-400 VND/kg in 2005 (Thanh; 2007). The current analysis shows that effective implementation of the actual levels of emission charge rates would lead producers to choose current TSS pollution emission levels as their optimal response, if the TSS semi-elasticity was around 5E5. This corresponds to a situation where a representative medium-sized manufacturing company, with a 10 Bio. VND turnover, would achieve a 50% reduction in TSS emissions through a yearly variable pollution treatment cost of 10,000 VND (<1US$). This condition is not likely to be fulfilled. The following conclusion emerges:

- Current TSS emission charge rates (200-400 VND/kg) are, significantly, below the levels of emission charge rates, which, through effective implementation, would lead producers to reduce TSS pollution emissions below current levels.

As noted above, TSS emissions are estimated to increase from 6,050 tons in 2005 to 7,230 tons in 2006 and 14,670 tons in 2010 as a consequence of the 2006-2010 SEDP development plan. The results in Table 5 confirm that the growth rates for the optimal emission charge rate – the growth rates which would ensure that TSS emissions stayed at the 2005 level over the period 2006-2010 – are invariant to the parameter value of the semi-elasticity. Accordingly, in order to maintain TSS emissions at the 2005 level, the emission charge rate would have had to increase by 18-20% in 2006 and by 132-143% in 2010, over the base run level.

Table 6 presents measures of producer costs and economy-wide efficiency losses. Producer costs include emission charges and treatment costs. The results indicate that, regardless of parameter values, the optimal increase in the emission charge rate will lead to a reduction in fiscal revenues from emission charges. Accordingly, producers will increase pollution treatment and reduce pollution emissions in order neutralize the increase in emission charge rates. However, the price of reduced pollution emissions is increasing treatment costs. The results show that the reduction in emission charge payments will, always, be dominated by a very strong relative increase in pollution treatment costs. These conclusions mirror the conclusions from the previous section.

In the case of a semi-elasticity of 13,000, the optimal emission charge rate increases from a base run value of 10,700 VND/kg to 12,800 VND/kg in 2006 and 25,900 VND/kg in 2010. Due to increased pollution treatment, total emission charge payments drops by around 5 Mio. VND in 2006 and 40 Mio. in 2010. At the same time, the threat of increased emission charge collections leads producers to increase pollution treatment costs by 17.5 Bio. VND in 2006 and 218.1 Bio. VND in 2010. It follows that total producer costs increases by around 17.5 Bio. in 2006 and around 218 Bio. VND in 2010.

Table 7. Optimal Emission Charges Rate to maintain BOD Emissions at the 2005 level as part of the 2006-2010 SEDP development plan

	2006						
Elasticity[1]	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Emissions (Base Run)[2]	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Emission Charge Rate (100 VND/kg)	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Emissions (2005 level)[2]	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Optimal Emission Charge Rate (100 VND/kg)	10.9	5.1	3.5	2.9	2.7	2.5	2.5
Emissions change (%)	-17%	-17%	-17%	-17%	-17%	-17%	-17%
Emission Charge Rate change (%)	445%	157%	76%	46%	33%	27%	24%

	2010						
Elasticity[1]	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Emissions (Base Run)[2]	13.9	13.9	13.9	13.9	13.9	13.9	13.9
Emission Charge Rate (100 VND/kg)	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Emissions (2005 level)[2]	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Optimal Emission Charge Rate (100 VND/kg)	8,503.6	213.5	33.0	13.0	8.1	6.4	5.7
Emissions change (%)	-61%	-61%	-61%	-61%	-61%	-61%	-61%
Emission Charge Rate change (%)	425081%	10574%	1549%	548%	306%	221%	186%

Source: Own Calculations; [1] Semi-elasticity of pollution emission coefficient with respect to treatment cost rate; [2] tons/year

Table 8. Emissions Charges, Treatment Costs and Efficiency Losses from maintaining BOD Emissions at the 2005 level, as part of the 2006-2010 SEDP development plan

	2006						
Elasticity[1]	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Emissions (Base Run)[2]	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Emission Charges (bio. VND)	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Treatment Costs (bio. VND)	0.2	0.4	0.8	1.6	3.2	6.4	12.9
GDP (bio. VND)	773,575.9	773,575.9	773,575.9	773,575.9	773,575.9	773,575.9	773,575.9
Emissions (2005 level)[2]	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Optimal Emission Charges (bio. VND)	7.3	3.4	2.3	1.9	1.8	1.7	1.6
Treatment Costs (bio. VND)	0.9	0.9	1.2	1.9	3.5	6.7	13.2
GDP (bio. VND)	773,574.9	773,575.4	773,575.6	773,575.6	773,575.7	773,575.7	773,575.7
Emission Charges change (bio. VND)	5.7	1.8	0.7	0.3	0.2	0.1	0.0
Treatment Costs change (bio. VND)	0.7	0.5	0.4	0.3	0.3	0.3	0.3
GDP change (bio. VND)	-1.1	-0.5	-0.4	-0.3	-0.3	-0.3	-0.3

	2010						
Elasticity[1]	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Emissions (Base Run)[2]	13.9	13.9	13.9	13.9	13.9	13.9	13.9
Emission Charges (bio. VND)	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Treatment Costs (bio. VND)	0.6	1.2	2.3	4.6	9.3	18.5	37.0
GDP (bio. VND)	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4
Emissions (2005 level)[2]	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Optimal Emission Charges (bio. VND)	7,844.4	194.2	30.0	11.8	7.4	5.8	5.2
Treatment Costs (bio. VND)	980.5	48.5	15.0	11.8	14.8	23.4	41.6
GDP (bio. VND)	1,037,433.6	1,038,822.3	1,038,860.3	1,038,865.5	1,038,867.0	1,038,867.5	1,038,867.8
Emission Charges change (bio. VND)	7,839.7	189.5	25.4	7.2	2.8	1.2	0.6
Treatment Costs change (bio. VND)	980.0	47.4	12.7	7.2	5.5	4.9	4.6
GDP change (bio. VND)	-1,437.8	-49.1	-11.1	-5.9	-4.4	-3.9	-3.6

Source: Own Calculations; [1] Semi-elasticity of pollution emission coefficient with respect to treatment cost rate; [2] tons/year

The increased producer costs leads to an economy-wide efficiency loss in terms of a reduction in GDP. In the case of a semi-elasticity of 13,000, the economy-wide efficiency loss will amount to a 73.8 Bio. VND reduction in real GDP in 2010. This amounts to around 0.007% of GDP. The following conclusions emerge from above analysis:

- The optimal level of the TSS emission charge rate varies inversely with the parameter value of the semi-elasticity,
- The optimal growth rates of the TSS emission charge rate are relatively invariant with respect to the parameter values of the semi-elasticity, and
- Under certain conditions, TSS emissions could have been controlled, as part of the 2006-2010 SEDP development plan, through effective implementation and moderate expansion of the optimal emission charge rate. Such a scenario would have been accompanied by a marginal reduction in fiscal revenues and a relatively minor economy-wide efficiency loss.

The conditions under which BOD emissions could be controlled, as part of the 2006-2010 SEDP plan, at a reasonable cost, refers to the situation where the 'semi-elasticity of the pollution emission rate with respect to the treatment cost rate' is greater than 5000. This condition is similar to the condition from the previous section. Accordingly, the condition reflects a situation where e.g. a representative medium-sized manufacturing company, with a 10 Bio. VND turnover, would achieve a 50% reduction in TSS emissions through a yearly variable pollution treatment cost of 1 Mio. VND.

3.2. Fixed Elasticity of Pollution Emission Rate

The simulations of this section are based on the assumption of a fixed *elasticity* of the pollution emission rate with respect to the treatment cost rate. Accordingly, the CGE model, which is employed in this section, is extended by the twin relationships of VAP2 and CP2, which were derived from the producer's pollution treatment problem with a fixed elasticity of the pollution emission rate with respect to the treatment cost rate (see section 2.1).

In contrast to the previous section, the current specification (based on a fixed elasticity of the pollution emission rate with respect to the treatment cost rate) is calibrated in such a way that current pollution emissions represent the optimal response to current emission charges. In particular, the calibration procedures were based on a BOD emission charge of 200 VND/kg and a TSS emission charge of 400 VND/kg.[4] [5]

[4] A 400 VND/kg emission charge represents the upper limit of current TSS emission charge rates according to decree No. 67/2003/ND-CP (Thanh; 2007). No information was available on current BOD emission charge rates. The 200 VND/kg emission charge for BOD pollution emissions was chosen, randomly.

3.2.1. Biological Oxygen Demand (BOD)

Table 7 presents the results of the simulations of optimal pollution emission charge rates, which would have been necessary to implement (effectively) as part of the 2006-2010 SEDP plan, in order to maintain BOD emissions at the 2005 level. Again, optimal emission charge rates are given under the label ‘optimal emission charge rate’, while counterfactual base run emission charge rates are given under the ‘emission charge rate’ label. As noted in the introduction to this section, the base run BOD emission charge rate was set to 200 VND/kg as part of the calibration procedure. Accordingly, in this section, current levels of BOD pollution emissions represents the optimal response to a BOD emission charge rate of 200 VND/kg, given (i) the effective implementation of emission charge rates, and (ii) the elasticity of the pollution emission rate with respect to the treatment cost rate.

The sensitivity analyses in Table 7 shows that the base run emission charge rate is constant and invariant to changes in the parameter value of the ‘elasticity of the pollution emission rate with respect to the treatment cost rate’. This reflects that the base run emission charge rate was set to 200 VND/kg as part of the calibration procedure. The constant and invariant level of the base run emission charge rate is a special feature of the current model specification. Accordingly, base run emission charge rates varied inversely with the parameter value of the semi-elasticity in the previous section. Nevertheless, the following analysis will demonstrate that it remains crucial to obtain a proper elasticity estimate in order to make a proper assessment of the appropriate growth path for emission charge rates, i.e. the growth path which would lead producers to increase future pollution treatment and, thereby, reduce future emission levels.

As noted above, the BOD emission levels are estimated to increase from 5,450 tons in 2005 to 6,580 tons in 2006 and 13,880 tons in 2010 as a consequence of the 2006-2010 SEDP development plan. Table 7 provides estimates of optimal emission charge rates, which would have allowed the government to control BOD emissions at the 2005 level. The results indicate that the optimal yearly growth rates for emission charge rates are inversely related to the parameter value of the elasticity. Based on an elasticity of 1.0, optimal growth rates would have been 46% in 2006 and 548% in 2010, while, based on an elasticity of 8.0, optimal growth rates would have been 24% in 2006 and 186% in 2010, relative to the base run level (200 VND/kg).

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[5] It is noted that the optimal level of emission charge rates is positively related to the treatment cost rate. This was the case in the previous section 3.1, and it is also the case in the current section 3.2. In the calibration of the model, in this section, implied treatment cost rates were derived from the imposition of emission charge rates. This is opposite to the calibration procedure of the previous section, where emission charge rates were derived from the imposition of treatment cost rates.

These results demonstrate a crucial difference in the implications of the fixed semi-elasticity approach of the previous section and the fixed elasticity approach of the current section. The fixed semi-elasticity approach implies that optimal growth rates (of emission charge rates) are relatively invariant to the parameter value of semi-elasticity. In contrast, the elasticity approach implies that optimal growth rates (of emission charge rates) are varying, strongly, with the parameter value of the elasticity. The current approach, therefore, indicates that it is crucial to obtain a proper elasticity estimate in order to make a proper assessment of the appropriate growth path for future emission charge rates.

Table 8 presents measures of producer costs and economy-wide efficiency losses. Producer costs include emission charges and treatment costs. The results indicate that, regardless of the elasticity value, the optimal increase in the emission charge rate will lead to an increase in fiscal revenues. This conclusion differs from the conclusion of the previous section. Accordingly, the current results indicate that producers will increase pollution treatment costs and, thereby, reduce pollution emissions in order to reduce the increase in emission charge payments. However, they will not increase pollution treatment costs in such a way as to neutralize the impact on emission charge payments (as was the case in the fixed semi-elasticity approach of the previous section).

The level of producer costs varies, strongly, with the parameter value of the elasticity. The optimal increase in producer costs in 2010 amounts to 14.4 Bio. VND if the elasticity is 1.0. In comparison, the optimal increase in producer costs is 6.1 Bio. VND if the elasticity is 4.0, and 236.9 Bio. VND if the elasticity is 0.25. The composition of producer costs also varies with the parameter value of the elasticity. Based on an elasticity of 1.0, producers will balance the increase in pollution treatment costs and emission charge payments (7.2 Bio./7.2 Bio.). When the elasticity is larger than 1.0, producers will increase treatment costs relatively strongly, since they achieve a relatively large reduction in emission charge payments from a given increase in treatment costs (4.9 Bio./1.2 Bio.; elasticity=4.0). It follows that the expansion in fiscal revenues will be relatively small (relative to the expansion of treatment costs). On the other hand, if the elasticity is smaller than 1.0, producers will increase treatment costs relatively little, since they achieve a relatively small reduction in emission charge payments from a given increase in treatment costs (47.4 Bio./189.5 Bio.; elasticity=0.25). In this case, the expansion in fiscal revenues will be relatively large (relative to the expansion of treatment costs).

The analysis seems to suggest that emission charges, under certain conditions, can be used as an efficient instrument to achieve the twin goals of reducing pollution emissions and increasing fiscal revenues. Nevertheless, increasing emission charge collections may be a costly way of raising fiscal revenues. Since emission charges increase with the level of production, it is akin to a production tax. As such, it enters into the producer's production decision problem, and affects the level of value added creation. Emission charges are, therefore, likely to lead to relatively strong distortions in the allocation of resources, and to relatively strong reductions in economy-wide welfare.

The reduction in real GDP in 2010 amounts to 5.9 Bio. VND or 80% of the increase in fiscal revenues (7.2 Bio. VND) if the elasticity is 1.0. When the elasticity is higher than 1.0, the relative reduction in real GDP increases above 100%. On the other hand, when the elasticity is smaller than 1.0, the relative reduction in real GDP drops below 50%. Accordingly, the reduction in real GDP in 2010 amounts to 11.1 Bio. VND or 40% of the increase in fiscal revenues (25.4 Bio. VND) if the elasticity is 0.5. It follows that emission charges is an efficient tool for increasing fiscal revenues, when the emission coefficient elasticity is small. However, this also the case where pollution treatment is a relatively inefficient tool for reducing pollution emissions, and where emission charges, therefore, has the smallest impact on pollution emissions. The standard tax-policy conclusion emerges:

- If an emission charge is a potent tool for reducing BOD emissions (i.e. if the BOD emission coefficient elasticity is high), the emission charge is a relatively inefficient tool for raising fiscal revenues, and vice versa.

The following conclusions emerge from above analysis:

- The optimal growth rates of the BOD emission charge rate varies with the parameter values of the emission coefficient elasticity, and
- Under certain conditions, BOD emissions could have been controlled, as part of the 2006-2010 SEDP development plan, through effective implementation and moderate expansion of the optimal emission charge rate. Such a scenario would have been accompanied by an expansion in fiscal revenues and a relatively minor economy-wide efficiency loss (which could, potentially, exceed the fiscal revenue expansion).

The conditions under which BOD emissions could be controlled, as part of the 2006-2010 SEDP plan, at a reasonable cost, refers to the situation where the ‘semi-elasticity of the pollution emission rate with respect to the treatment cost rate’ is less than 1.0. This condition reflects a situation where e.g. a representative medium-sized manufacturing company, with a turnover of 10 Bio. VND and initial treatment costs of 10 Mio. VND, would achieve a 50% reduction in BOD emissions through a 50% (5 Mio. VND) increase in variable pollution treatment costs.

Table 9. Optimal Emission Charges Rate to maintain TSS Emissions at the 2005 level as part of the 2006-2010 SEDP development plan

	2006						
Elasticity[1]	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Emissions (Base Run)[2]	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Emission Charge Rate (100 VND/kg)	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Emissions (2005 level)[2]	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Optimal Emission Charge Rate (100 VND/kg)	19.8	9.7	6.8	5.7	5.2	5.0	4.9
Emissions change (%)	-16%	-16%	-16%	-16%	-16%	-16%	-16%
Emission Charge Rate change (%)	396%	143%	71%	43%	31%	25%	22%

	2010						
Elasticity[1]	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Emissions (Base Run)[2]	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Emission Charge Rate (100 VND/kg)	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Emissions (2005 level)[2]	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Optimal Emission Charge Rate (100 VND/kg)	10,754.7	335.1	57.0	23.5	15.1	12.1	10.8
Emissions change (%)	-59%	-59%	-59%	-59%	-59%	-59%	-59%
Emission Charge Rate change (%)	268768%	8277%	1326%	488%	278%	203%	171%

Source: Own Calculations; [1] Elasticity of pollution emission coefficient with respect to treatment cost rate; [2] tons/year

Table 10. Emissions Charges, Treatment Costs and Efficiency Losses from maintaining TSS Emissions at the 2005 level, as part of the 2006-2010 SEDP development plan

	2006						
Elasticity[1]	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Emissions (Base Run)[2]	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Emission Charges (bio. VND)	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Treatment Costs (bio. VND)	0.4	0.9	1.8	3.5	7.0	14.0	28.0
GDP (bio. VND)	773,575.9	773,575.9	773,575.9	773,575.9	773,575.9	773,575.9	773,575.9
Emissions (2005 level)[2]	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Optimal Emission Charges (bio. VND)	14.6	7.1	5.0	4.2	3.8	3.7	3.6
Treatment Costs (bio. VND)	1.8	1.8	2.5	4.2	7.7	14.7	28.7
GDP (bio. VND)	773,574.0	773,574.9	773,575.2	773,575.3	773,575.4	773,575.4	773,575.4
Emission Charges change (bio. VND)	11.0	3.6	1.5	0.7	0.3	0.2	0.1
Treatment Costs change (bio. VND)	1.4	0.9	0.7	0.7	0.7	0.6	0.6
GDP change (bio. VND)	-2.0	-1.0	-0.7	-0.6	-0.6	-0.5	-0.5

	2010						
Elasticity[1]	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Emissions (Base Run)[2]	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Emission Charges (bio. VND)	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Treatment Costs (bio. VND)	1.1	2.3	4.6	9.2	18.3	36.7	73.4
GDP (bio. VND)	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4	1,038,871.4
Emissions (2005 level)[2]	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Optimal Emission Charges (bio. VND)	10,383.5	317.1	54.0	22.2	14.3	11.4	10.2
Treatment Costs (bio. VND)	1,297.9	79.3	27.0	22.2	28.6	45.8	82.0
GDP (bio. VND)	1,036,950.5	1,038,790.7	1,038,851.5	1,038,860.5	1,038,863.1	1,038,864.1	1,038,864.5
Emission Charges change (bio. VND)	10,374.3	307.9	44.8	13.1	5.1	2.3	1.1
Treatment Costs change (bio. VND)	1,296.8	77.0	22.4	13.1	10.2	9.1	8.6
GDP change (bio. VND)	-1,920.9	-80.7	-19.9	-10.9	-8.3	-7.3	-6.9

Source: Own Calculations; [1] Elasticity of pollution emission coefficient with respect to treatment cost rate; [2] tons/year

3.2.2. Total Suspended Solids (TSS)

Table 9 presents the results of the simulations of optimal pollution emission charge rates, which would have been necessary to implement (effectively) as part of the 2006-2010 SEDP plan, in order to maintain TSS emissions at the 2005 level. Again, optimal emission charge rates are given under the label 'optimal emission charge rate', while counterfactual base run emission charge rates are given under the 'emission charge rate' label. As noted in the introduction to this section, the base run TSS emission charge rate was set to 400 VND/kg as part of the calibration procedure. This corresponds to the upper limit of current TSS emission charge rates according to decree No. 67/2003/ND-CP (Thanh; 2007). It follows that, in this section, current levels of TSS pollution emissions represents the optimal response to a TSS emission charge rate of 400 VND/kg, given (i) the effective implementation of emission charge rates, and (ii) the elasticity of the pollution emission rate with respect to the treatment cost rate.

The sensitivity analyses in Table 9 shows that the base run emission charge rate is constant and invariant to changes in the parameter value of the 'elasticity of the pollution emission rate with respect to the treatment cost rate'. This mirrors the simulations in the previous section, and it reflects that the base run emission charge rate was set to 400 VND/kg as part of the calibration procedure. As noted above, TSS emissions are estimated to increase from 6,050 tons in 2005 to 7,230 tons in 2006 and 14,670 tons in 2010 as a consequence of the 2006-2010 SEDP development plan. Table 9 provides estimates of optimal emission charge rates, which would have allowed the government to control TSS emissions at the 2005 level. The results indicate that the optimal yearly growth rates for emission charge rates are inversely related to the parameter value of the elasticity. Based on an elasticity of 1.0, optimal growth rates would have been 43% in 2006 and 488% in 2010, while, based on an elasticity of 8.0, optimal growth rates would have been 22% in 2006 and 171% in 2010, relative to the base run level (400 VND/kg).

It follows that, in order to control TSS emissions at the 2005 level, as part of the 2006-2010 SEDP development plan, the TSS emission charge rate would have had to increase from 400 VND/kg to 490 VND/kg in 2006 and to 1,080 VND/kg in 2010. These numbers apply if the parameter value of the emission coefficient elasticity is 8.0. If the elasticity is smaller, the growth rates become higher. Accordingly, the TSS emission charge rate would have had to increase from 400 VND/kg to 570 VND/kg in 2006 and to 2,350 VND/kg in 2010. Once again, these results demonstrate the crucial importance of obtaining a proper elasticity estimate in order to project the appropriate growth path for future emission charge rates.

Table 10 presents measures of producer costs and economy-wide efficiency losses. Producer costs include emission charges and treatment costs. The results indicate that, regardless of the elasticity value, the optimal increase in the emission charge rate will lead to an increase in fiscal revenues. This conclusion mirrors the conclusion of the previous section. Accordingly, the results indicate that producers will increase pollution treatment costs and, thereby, reduce pollution emissions in order to reduce the increase in emission charge payments. However, emission charge payments – and, hence, fiscal revenues – will always increase, regardless of the parameter value of the elasticity.

The level of producer costs also varies, strongly, with the parameter value of the elasticity. The optimal increase in producer costs in 2010 amounts to 26.2 Bio. VND if the elasticity is 1.0. In comparison, the optimal increase in producer costs is 11.4 Bio. VND if the elasticity is 4.0, and 384.9 Bio. VND if the elasticity is 0.25. The composition of producer costs also varies with the parameter value of the elasticity. Based on an elasticity of 1.0, producers will balance the increase in pollution treatment costs and emission charge payments (13.1 Bio./13.1 Bio.). When the elasticity is larger than 1.0, producers will increase treatment costs relatively strongly, since they achieve a relatively large reduction in emission charge payments from a given increase in treatment costs (9.1 Bio./2.3 Bio.; elasticity=4.0). It follows that the expansion in fiscal revenues will be relatively small (relative to the expansion of treatment costs). On the other hand, if the elasticity is smaller than 1.0, producers will increase treatment costs relatively little, since they achieve a relatively small reduction in emission charge payments from a given increase in treatment costs (77.0 Bio./307.9 Bio.; elasticity=0.25). In this case, the expansion in fiscal revenues will be relatively large (relative to the expansion of treatment costs).

The current results mirror the results from the previous section, qualitatively. Accordingly, the current analysis, also, seems to suggest that emission charges, under certain conditions, can be used as an efficient instrument to achieve the twin goals of reducing pollution emissions and increasing fiscal revenues. But the current results can, also, be used to demonstrate (as shown in the previous section) that the efficiency of emission charges in raising fiscal revenues, is inversely related to the efficiency of emission charges in reducing pollution emissions. In particular, the current results show that the ratio between the efficiency loss (reduction in real GDP) and fiscal revenue expansion increases above 100% when the emission coefficient elasticity is higher than 2.0, while it drops below 50% when the elasticity is lower than 0.5. Once again, the standard tax-policy conclusion emerges:

- If an emission charge is a potent tool for reducing TSS emissions (i.e. if the TSS emission coefficient elasticity is high), the emission charge is a relatively inefficient tool for raising fiscal revenues, and vice versa.

The following conclusions emerge from above analysis:

- The optimal growth rates of the TSS emission charge rate varies with the parameter values of the emission coefficient elasticity, and
- Under certain conditions, TSS emissions could have been controlled, as part of the 2006-2010 SEDP development plan, through effective implementation and moderate expansion of the optimal emission charge rate. Such a scenario would have been accompanied by an expansion in fiscal revenues and a relatively minor economy-wide efficiency loss (which could, potentially, exceed the fiscal revenue expansion).

The above conclusions mirror the conclusions from the previous section. As was the case in the previous section, the conditions under which TSS emissions could be controlled, as part of the 2006-2010 SEDP plan, at a reasonable cost, refers to the situation where the 'semi-elasticity of the pollution emission rate with respect to the treatment cost rate' is less than 1.0. Again, this reflects a situation where e.g. a representative medium-sized manufacturing company, with a turnover of 10 Bio. VND and initial treatment costs of 10 Mio. VND, would achieve a 50% reduction in BOD emissions through a 50% (5 Mio. VND) increase in variable pollution treatment costs.

4. Conclusion

The current study has derived optimal growth paths for pollution emission charges, in order to control future water pollution emissions in the Vietnamese manufacturing sector. A prior study estimated the manufacturing sector pollution impact of the 2006-2010 SEDP development plan for Vietnam (Jensen et al.; 2008). That study demonstrated that pollution emissions are going to expand, strongly, as a consequence of the 2006-2010 SEDP development plan. As an extension to the prior study, the current study has demonstrated that effective implementation and moderate expansion of optimal emission charges, under certain conditions, could have been used, as part of the 2006-2010 SEDP development plan, to control pollution emissions at 2005 levels. Such a scenario would have been accompanied by a moderate expansion in fiscal revenues and a relatively minor economy-wide efficiency loss (which could, potentially, exceed the fiscal revenue expansion).

The current study, therefore, suggests that effective implementation and gradual expansion of pollution emission charges should be incorporated into future SEDP development plans, in order to keep control over the, otherwise, uncontrolled expansion of pollution emissions. The gradual expansion of emission charges is unlikely to increase government revenue collection in any major way. Accordingly, the current study demonstrates that if an emission charge is a potent tool for reducing pollution emissions, it will automatically be a relatively inefficient tool for raising fiscal revenues. Emission charges should therefore be considered, not as a revenue collection tool, but as a tool for pollution emission control. A key determinant of the efficiency of pollution emission charges is the elasticity (semi-elasticity) of the pollution emission rate with respect to the pollution treatment rate. In order to derive optimal emission charge growth paths, for incorporation into future SEDP development plans, it is, therefore, crucial to obtain reliable elasticity (semi-elasticity) estimates.

Finally, it is highlighted that the economy-wide efficiency losses, which are associated with the implementation of emission charges, seem to be relatively small. If pollution emissions were to be controlled by forced reductions in production output, a 1% reduction in manufacturing pollution emissions could, in the extreme, lead to a 0.5% reduction in real GDP. In contrast, the current study demonstrates that a gradual expansion of emission charges, under general conditions, can achieve a 60% reduction in water pollution emissions in the manufacturing sector with an accompanying economy-wide efficiency loss of 0.01% of real GDP. Effective implementation of emission charges is, therefore, likely to be a very potent and cost-effective tool for controlling pollution emissions as development progresses in Vietnam.

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Appendix A: Solution of the producer's pollution treatment problem

The producer's basic objective function for cost minimization in relation to pollution treatment (OBJ) includes emission charges (EMC) and pollution treatment costs (PTC = IVP + VAP):

$$\begin{aligned} OBJ &= EMC + PTC \\ &= EMC + (IVP + VAP) \end{aligned}$$

where $EMC = Emission\ Charges\ (Mio.\ VND)$
$PTC = Pollution\ Treatment\ Cost\ (Mio.\ VND).$
$IVP = Fixed\ Pollution\ Treatment\ Cost\ (Mio.\ VND).$
$VAP = Variable\ Pollution\ Treatment\ Costs\ (Mio.\ VND)$

Defining total emission charges as the product of an emission charge per unit of emissions (tp), an emission coefficient per real value unit of production (cp) and the real value of production ($\sum_{t=1}^{T} X_t$), the objective function may be re-stated as:

$$OBJ = tp * cp * \sum_{t=1}^{T} X_t + IVP + VAP$$

where $tp = emission\ charges\ rate\ (Mio.\ VND/kg)$
$cp = emission\ coefficient\ rate\ (kg/Mio.\ VND)$
$\sum_{t=1}^{T} X_t = production\ value\ over\ planning\ horizon\ (Mio.\ VND)$

Finally, defining fixed and variable pollution treatment costs (IVP resp. VAP) as the product of pollution treatment cost rates (ivp resp. vap) and the real value of production (X), the objective function may once again be re-stated as:

$$OBJ = tp * cp * \sum_{t=1}^{T} X_t + ivp * \sum_{t=1}^{T} X_t + vap * \sum_{t=1}^{T} X_t$$

where $vap = VAP/\sum_{t=1}^{T} X_t = variable\ pollution\ treatment\ cost\ rate$ (%)
$ivp = IVP/\sum_{t=1}^{T} X_t = investment\ pollution\ treatment\ cost\ rate$ (%)

Until now, the re-statements of the producer's pollution treatment problem have only involved definitions. No assumptions have been made so far. The following assumptions will be made for the solution of the producer's cost minimization problem:

(Ass. 1) $ivp = b * vap$

(Ass. 2a) $ln(cp) = -a1 * vap$

(Ass. 2b) $ln(cp) = -a2 * \ln(vap)$

Assumption 1 says that the investment pollution treatment cost rate (ivp) vary in proportion to the variable pollution treatment cost rate (vap). Assumption 2a resp. 2b states that the semi-elasticity resp. elasticity of the pollution emission coefficient (cp) with respect to the variable pollution treatment cost rate (vap) is fixed. These assumptions give rise to two distinct optimization problems.

First, the combination of assumptions 1 and 2a forms the following optimization problem, which is based on a fixed semi-elasticity of the pollution emission coefficient (cp) with respect to the variable pollution treatment cost rate (vap):

(OPT 1)
$$Min_{vap}\ tp * cp * \sum_{t=1}^{T} X_t + ivp * \sum_{t=1}^{T} X_t + vap * \sum_{t=1}^{T} X_t$$
$$s.t. \quad ivp = b * vap$$
$$ln(cp) = -a1 * vap$$

The implications of the optimization problem (A4) are derived in the section A.1.

Second, the combination of assumptions 1 and 2b gives rise to the following optimization problem, which is based on a fixed elasticity of the pollution emission coefficient (cp) with respect to the variable pollution treatment cost rate (vap):

(OPT 2)
$$Min_{vap}\ tp * cp * \sum_{t=1}^{T} X_t + ivp * \sum_{t=1}^{T} X_t + vap * \sum_{t=1}^{T} X_t$$
$$s.t. \quad ivp = b * vap$$
$$ln(cp) = -a2 * \ln(vap)$$

The implications of the optimization problem (A5) are derived in the section A.2.

In the solution of the minimization problems, the government chooses tp to provide price incentives for the producer to undertake pollution treatment, while the producer chooses vap to minimize total pollution emission charges and treatment costs. The impact of pollution emission charges and treatment costs on aggregate production decisions ($\sum_{t=1}^{T} X_t$) are captured through re-specification of the remaining optimality conditions in the CGE model.

A.1. Producer's pollution treatment problem with fixed emission coefficient semi-elasticity

The combination of assumptions 1 and 2a forms the following optimization problem:

(OPT 1) $$Min_{vap}\ tp * cp * \sum_{t=1}^{T} X_t + ivp * \sum_{t=1}^{T} X_t + vap * \sum_{t=1}^{T} X_t$$

$$s.t. \quad ivp = b * vap$$
$$ln(cp) = -a1 * vap$$

Substitution of the sub-constraints into the objective function leads to the following re-specified objective function:

(OBJ 1) $$OBJ = tp * \exp(-a1 * vap) * \sum_{t=1}^{T} X_t + b * vap * \sum_{t=1}^{T} X_t + vap * \sum_{t=1}^{T} X_t$$
$$= tp * \exp(-a1 * vap) * \sum_{t=1}^{T} X_t + (1+b) * vap * \sum_{t=1}^{T} X_t$$

The first order condition for cost minimization, based on the objective function (OBJ 4), can now be derived as:

(FOC 1) $$-a1 * tp * \exp(-a1 * vap) * \sum_{t=1}^{T} X_t + (1+b) * \sum_{t=1}^{T} X_t = 0$$

The first order condition (FOC 1) can be solved for the optimal level of vap as a function of tp:

$$vap^*(tp) = \frac{1}{a1} \ln(a1 * tp) - \frac{1}{a} \ln(1+b)$$

In the implementation of the optimality condition within the CGE model, investment costs will be disregarded. Accordingly, the optimal solution for the variable pollution treatment cost rate (vap*) will be approximated by:

(VAP 1) $$vap^*(tp) \approx \frac{1}{a1} \ln(a1 * tp)$$

Based on the above solution for the variable pollution treatment cost rate (VAP 1), the implied optimal pollution emission coefficient (cp*) may be expressed as a function of the emission charge rate (tp):

(CP 1) $$cp^*(tp) \approx \frac{1}{a1 * tp}$$

Equations (VAP 1) and (CP 1) will form the basis for the implementation of the producer's pollution treatment problem, based on a fixed 'semi-elasticity of the pollution emission coefficient (cp) with respect to the variable pollution treatment cost rate (vap)'.

A.2. Producer's pollution treatment problem with fixed emission coefficient elasticity

The combination of assumptions 1 and 2a forms the following optimization problem:

(OPT 2) $$Min_{vap}\ tp * cp * \sum_{t=1}^{T} X_t + ivp * \sum_{t=1}^{T} X_t + vap * \sum_{t=1}^{T} X_t$$

$$s.t. \quad ivp = b * vap$$
$$ln(cp) = -a2 * \ln(c * vap)$$

Substitution of the sub-constraints into the objective function leads to the following re-specified objective function:

(OBJ 2) $$OBJ = tp * c * vap^{-a2} * \sum_{t=1}^{T} X_t + b * vap * \sum_{t=1}^{T} X_t + vap * \sum_{t=1}^{T} X_t$$
$$= c * tp * vap^{-a2} * \sum_{t=1}^{T} X_t + (1+b) * vap * \sum_{t=1}^{T} X_t$$

The first order condition for cost minimization, based on the objective function (OBJ 2), can now be derived as:

(FOC 2) $$-a2 * c * tp * vap^{-a2-1} * \sum_{t=1}^{T} X_t + (1+b) * \sum_{t=1}^{T} X_t = 0$$

The first order condition (FOC 2) can be solved for the optimal level of vap as a function of tp:

$$vap^*(tp) = \left[\frac{a2 * c * tp}{1+b}\right]^{1/(1+a2)}$$

Again, investment costs will be disregarded in the implementation of the producer's pollution treatment problem within the CGE model. Accordingly, the optimal solution for the variable pollution treatment cost rate (vap*) will be approximated by:

(VAP 2) $$vap^*(tp) \approx c^{1/(1+a2)} * [a2 * tp]^{1/(1+a2)}$$

Based on the above solution for the variable pollution treatment cost rate (VAP 2), the implied optimal pollution emission coefficient (cp*) may be expressed as a function of the emission charge rate (tp):

(CP 2) $$cp^*(tp) \approx c^{1/(1+a2)} * [a2 * tp]^{-a2/(1+a2)}$$

Equations (VAP 2) and (CP 2) will form the basis for the implementation of the producer's pollution treatment problem, based on a fixed 'elasticity of the pollution emission coefficient (cp) with respect to the variable pollution treatment cost rate (vap)'.