Economic Impact Analysis on China's Environmental Tax Reform through a Static Computable General Equilibrium Analysis

QIN Changbo*, WANG Jinnan, GE Chazhong, GAO Shuting LIU Qianqian

Environmental Economic Institute, Chinese Academy for Environmental Planning (CAEP),
Beijing 100012, China

Abstract：In this study, the GREAT-W model is further extended into the GeneRal Equilibrium Analysis sysTem for Environment (GREAT-E) to assess the economic impacts of China's environmental taxation reforming. The simulation results show that the imposition of environmental tax is of very limited impact on China's macro-economy, in which the reduction in GDP can be made within the affordable range. Relatively, the emission reduction effect of the imposition of environmental tax on the pollutants is much greater than its negative effect on the economic development. It suggests that imposing environmental taxes can lead to important shifts in production, consumption, value added, and trade patterns. In order to promote the internalization of environmental cost, it is suggested to raise the pollution tax/charge standard, and at the same time, the government should reduce the adverse impact in the imposition of environmental tax by such means as to relieve the income tax or to provide subsidies to the vulnerable groups.

Key words: China; Environmental taxation; CGE; Economic impact

Relative shortage of resources and limited environmental capacity have become the new basic characteristics of China's national conditions, whereas China's economic aggregate would continue to expand and the resources environment pressure would continue to increase. The imposition of environmental tax is one of the effective environmental economic means to promote China's energy conservation and emission reduction and the transition of development mode. It is put forward in the "Opinions on Strengthening the Work Focus in Environmental Protection (Guo Fa [2011] No. 35)" issued by the State Council in October 2011 to "actively promote the reform of environmental tax and charges and research the imposition of environmental protection tax", which has provided an opportunity for China's formulation and implementation of environmental tax.

1. Background

Environmental tax was first proposed by British economist Arthur C. Pigou in his research theory on externalities in 1920s. Pigou thought that it would be necessary for the government to make the environmental cost internalized through market intervention with the form of taxation or subsidy. The “Polluter Pays Principle (PPP)” formed in late 1960s has provided the theoretical basis for the determination of the taxation objects of environmental tax. The starting point of this principle is that the commodity prices should fully reflect not only the cost of production but also the cost of resources and pollution.

Environmental tax is helpful to promote the internalization of the external negative effects induced by the pollution emission and make producer strengthen the pollution control or adopt cleaner production technology to reduce the emission of pollutants. But the imposition of environmental tax would, to some extent, influence the cost of production, the supply and demand of commodities, and impact the economic growth and residential welfare. Therefore, these impacts of the environmental taxation policies need to be carefully instigated: What is the reasonable level of environmental tax rate? How would the environmental tax impact China’s pollution emission? To what extent would it impact China’s macro-economy? How does it influence China’s economic structure and trade structure?

As an effective policy analysis tool in the field of economics, the Computable General Equilibrium Model (referred to as the CGE model) can provide support in answering the above-mentioned questions and provide quantitative analysis for the economic influence and environmental impact of imposing the environmental tax. Wu and Xuan (2002) used a static CGE model to analyze the impacts of China’s sulfur tax policies. The results showed that the imposition of sulfur tax can lead to the negative effect on China’s GDP, but it would be beneficial to the adjustment of energy structure and economic structure to greatly reduce the emission of sulfur dioxide. Wang *et al.* (2005) discovered that the carbon tax could make the production of coal and natural gas decline through simulation analysis using CGE mode. Based on “Energy-Economy-Environment” CGE model, Pang *et al.* (2008) simulated the economic impact on China’s imposition of fuel tax. Qin *et al.* (2012) developed the GeneRal Equilibrium Analysis sysTem for Water (GREAT-W), an economy-wide static Walrasian CGE model with water as a production factor, to assess the likely effects of water tax charges on the Chinese economy. In this study, the GREAT-W model is further extended into the GeneRal Equilibrium Analysis sysTem for Environment (GREAT-E) to assess the economic impacts of China's environmental taxation reforming.

The paper is organized as follows. The second section discusses the CGE model, data, and parameters. The third section gives behind the simulations of environmental taxation policies. The fourth section analyzes the impact of environmental taxes on China's economy, and the final section presents the conclusion.

2. Analytical framework

This section describes the overview of the GREAT-E model, construction of the environmental extended social accounting matrix (ESAM).

2.1 GREAT-E model

The model is developed by using the mathematical program system for general equilibrium (MPSGE), which is a general algebraic modeling system (GAMS) extension developed by Rutherford (1998), with the MCP GAMS solver. Its theoretical structure is typical of most static CGE models, and consists of equations describing producers' demands for produced inputs and primary factors; producers' supplies of commodities; demands for capital investment; household demands; export demands; government demands; relationships of basic values to production costs and to purchasers' prices; market-clearing conditions for commodities and primary factors; and numerous other macro-economic variables and price indices (Robinson, 1999). The more detailed description of the model refers to Qin et al. (2011, 2012). Here, only a general description of the production structure is given in the following.

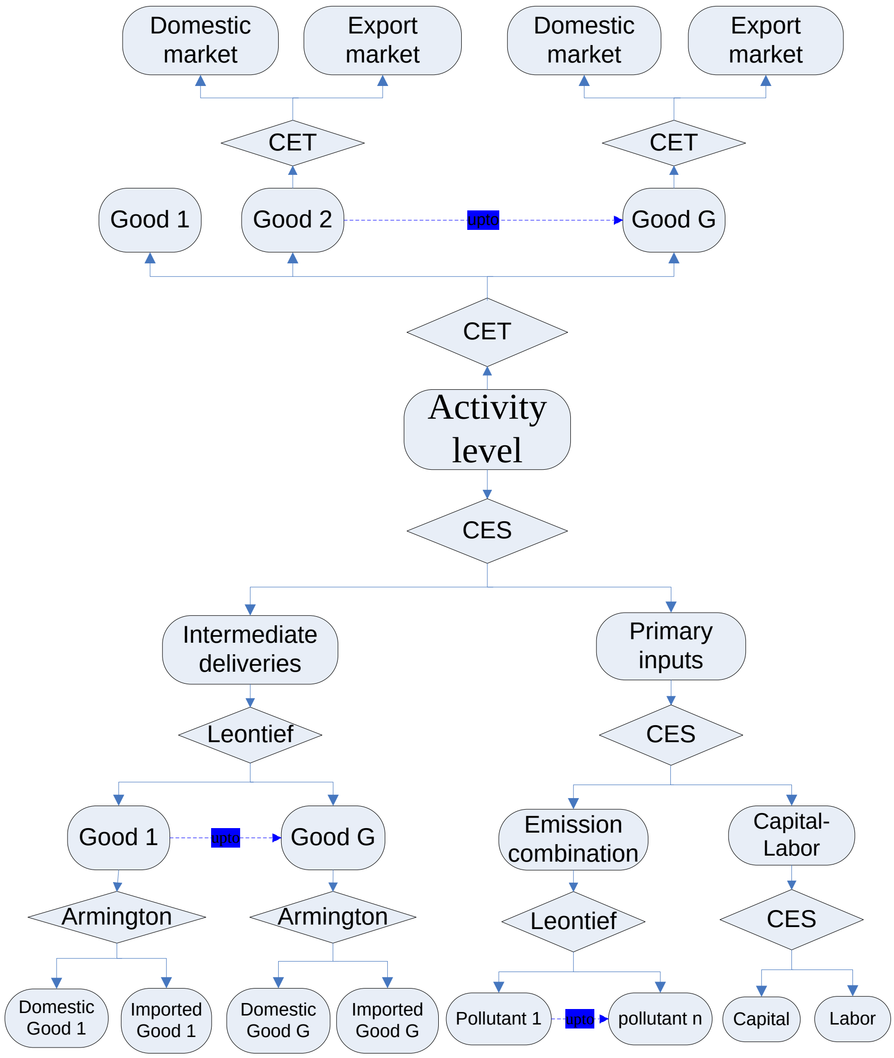

Figure 1. The structure of water CGE model

Figure 1 presents a diagrammatic overview of the structure of the model. The model uses multi-level nested production functions to determine the level of production. At the top level, the technology is specified by a constant elasticity of substitution (CES) function of two quantities: value-added and aggregated intermediate inputs. The aggregate intermediate input is determined by a Leontief function of disaggregated intermediate inputs, whereas value-added is itself a nested CES function of primary factors. Capital and labor are combined by a CES function at the bottom level, and this capital-labor composite is subsequently linked with emission combination by a CES function. Emission combination of different pollutants is determined by a Leontief function. This combination of composite primary inputs is the same across production sectors. However, this does not imply the same composite factor endowment combination for every product because shares of inputs and the elasticity parameters between inputs are not the same across the production sectors.

2.2 Environmental extended social accounting matrix

Due to the lack of an official social accounting matrix (SAM) published by government, we need to build a SAM by combining data from various sources into a consistent SAM framework. In this study, we present an environmental extended social accounting matrix (ESAM) which includes the pollution emission accounts.

Our ESAM for the Chinese economy includes 16 production sectors: crop cultivation and forestry (CCF), livestock and fishery (LSF), mining (MIN), food and tobacco (FOO), textiles and wearing apparel (TEX), wood, paper and printing (PPP), petroleum refining and coking (PET), chemicals (CHM), non-metallic products (NME), metal products (MET), machinery and equipment (MAC), Electro-communication and instruments (CCC), other manufacturing (OHM), electricity (ELE), construction (CON), and services (SER). The data on activities, commodities, and import and export accounts are based on the national input-output table of China's economy for the year 2007. The revenue of expenditure accounts for the government come from the *Finance Yearbook of China 2008* (MOF, 2008) and tax data come from the *Tax Yearbook of China 2008* (SAT, 2008). Household and government revenue and expenditure are adjusted based on the flow-of-funds accounts of the *China Statistical Yearbook 2008* (NBS, 2008).

In this study, four accounts for chemical oxygen demand (COD), one for ammonia nitrogen (NH3-N), sulfur dioxide (SO_2) and nitrogen oxide (NOx) are added into the SAM with their emissions as production factors. The simple version of China's ESAM for the year 2007 developed by the authors is shown in Table 1.

Table 1.The simple version of Chinese ESAM for the year 2007 (unit: 10^8 CNY)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
1.Activity		818859													818859
2.Commodity	552815								24317	72235		35191	95541	112780	892880
3.Labor	110047														110047
4.Capital	117478														117478
5.COD	103														103
6.NH3N	8														8
7.SO2	170														170
8.NOx	113														113
9.Rural			28652								12023		775		41451
10.Urban			81395								44179	5447	2940		133962
11.Enterprise				117478								2061	1606		121144
12.Government	38124	1433			103	8	170	113		13998	16643				70592
13.Rest of World		72588													72588
14.Savings-invest									17133	47729	48298	27894	-28274		112780
Total	818859	892880	110047	117478	103	8	170	113	41451	133962	121144	70592	72588	112780	

3. Experimental simulation scenarios

According to *Effluent Fee Charge Standards and Accounting Method* released by Chinese government，the effluent fee charges are 0.7 CNY/kg for COD, 0.875 CNY/kg for NH_3-N,0.63 CNY/kg for SO_2 and 0.63 CNY for NOx. China's current pollutant charge standards are much lower than the pollution control costs and pollution damage costs. In order to reduce the emission of pollutants through the internalization of environmental costs, it is necessary to raise the charge standards either to continue the implementation of the current effluent fee charge policies or to introduce the environmental tax policy in the future. In order to assess the impact of the imposition of environmental tax on China's economy and pollution emission reduction, this study sets one baseline scenario and four simulation scenarios to simulate the impacts of raise the charge standards. In the baseline scenario, it is supposed to translate the current pollution charge standards into the environmental tax rate. In the simulation scenarios, the imposition standards of the environmental tax are supposed to be respectively increased by two times, four times, six times and eight times as compared with the existing effluent charge standards. For specific imposition standards, please see the following Table 2.

Table 2. Setting of experimental simulation scenarios(unit: CNY/kg)

	Base	Scenario 1	Scenario 2	Scenario 3	Scenario 4
COD	0.7	1.4	2.8	4.2	5.6
NH_3-N	0.875	1.75	3.5	5.25	7.0
SO_2	0.63	1.26	2.52	3.78	5.04
NOx	0.63	1.26	2.52	3.78	5.04

4. Results and Discussion

4.1 The macro-level results

The imposition of environmental tax would result in very little impact on the real GDP, but it could obtain a relatively obvious effect on pollution emission reduction. As shown in the simulation results as given in Table 3, under the imposition standards of environmental tax to be increased by two times, four times, six times and eight times, the real GDP would only be decreased by 0.018, 0.055, 0.092 and 0.128%, respectively. Compared with the slight decline in GDP, the imposition of environmental tax would have a comparatively obvious effect on the reduction of pollutant emission. Under the imposition standard of environmental tax to be increased by eight times, the total emissions of COD, ammonia nitrogen, sulfur dioxide and nitrogen oxides would be decreased by 0.5%, 0.2%, 1.9% and 1.7%, respectively. On the whole, the emission reduction effect of the imposition of environmental tax on the atmospheric pollutants would be greater than that on the water pollutants. This is perhaps because the emission load of the atmospheric pollutants is greater than that of the water pollutants. The imposition of the higher environmental tax on the atmospheric pollutants can restrain the development of sectors with high-intensity emission of the atmospheric pollutants and promote the development of sectors with low-intensity emission of the atmospheric pollutants. Since some sectors of low-intensity emission of the atmospheric pollutants may discharge heavy intensity of the water pollutants, it would produce an offset effect on the emission reduction of the water pollutants.

Table 3. Results from simulations at the macro-level (%)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Real GDP	-0.018	-0.055	-0.092	-0.128
Total export	-0.056	-0.165	-0.272	-0.376
Total import	-0.073	-0.217	-0.358	-0.495
Wage rates	-0.206	-0.612	-1.010	-1.402
Capital rents	-0.142	-0.423	-0.698	-0.967
All Household income	-0.326	-0.970	-1.601	-2.221
Rural household income	-0.359	-1.068	-1.764	-2.447
Urban household income	-0.317	-0.942	-1.556	-2.158
Government income	0.714	2.119	3.494	4.841
COD emission	-0.073	-0.217	-0.360	-0.500
NH_3-N emission	-0.031	-0.093	-0.154	-0.214
SO_2 emission	-0.280	-0.827	-1.357	-1.870
NOx emission	-0.257	-0.754	-1.236	-1.703

The imposition of environmental tax would lead to the decline of the total quantity of import and export. This is because the imposition of environmental tax can increase the costs of production and affect the export competitiveness of products. In case that the environmental tax is increased to eight times of the imposition standards of the current pollution emission charges, the total export would face a decline of 0.38%. Due to the decline of the domestic demand, the total import would also have such a decline as to a certain extent. In case that the environmental tax is increased to eight times of the imposition standards of the current pollution emission charges, the total import would have a decline of 0.5%.

The imposition of environmental tax would reduce the household disposable income, but it could significantly increase the government income. The excessive imposition standards of environmental tax would affect the household income. Especially, the impact produced on the rural households would be greater than that on the urban households, which shows that the imposition of environmental tax would have even more obvious impact on the relatively vulnerable groups. This is mainly because the environmental tax pushes up the prices of goods and the vulnerable groups would have weaker bearing capability in respect to the rising prices. In case that the environmental tax is increased to eight times of the imposition standards of the current pollution emission charges, the government financial income could be increased by 4.8%. The increase of government income would enable the government to have the financial resources to reduce the negative effect produced by the imposition of environmental tax on the residents' welfare through income tax relief or subsidies on the vulnerable groups.

4.2 The sectoral results

Table 4 lists the percentage of changes in the output levels and prices of various sectors in case of China's imposition of environmental tax. With regard to the output level, the imposition of environmental tax would restrain such with high-intensity pollution emission, in which the higher the tax rate it is, the more obvious the restraining effect will be. As for sectors with low-intensity pollution, the imposition of environmental tax would, on the contrary, promote their development. The sector to be faced with the greatest decline of output level would be the electricity, followed by livestock and fishery, mining, food and tobacco, chemicals. As seen from the situation of changes of price levels, such sectors with greater increase of prices are often those sectors with greater decline of output levels. The electro-communication and instruments sector, service sector are sectors with greater increase of output levels, which is mainly because the production of some high-polluting sectors is restrained, their capitals and labor forces have been transferred into these relatively cleaner sectors.

Table 4. Results from simulations: changes in sectoral output (%)

Sectors	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price

CCF	-0.155	-0.129	-0.464	-0.383	-0.769	-0.634	-1.070	-0.880
LSF	-0.250	0.072	-0.743	0.216	-1.228	0.359	-1.706	0.502
MIN	-0.243	0.017	-0.720	0.050	-1.188	0.082	-1.646	0.113
FOO	-0.236	-0.015	-0.701	-0.044	-1.160	-0.072	-1.612	-0.099
TEX	-0.198	-0.014	-0.593	-0.041	-0.986	-0.066	-1.377	-0.091
PPP	-0.227	0.105	-0.674	0.313	-1.112	0.517	-1.543	0.719
PET	-0.176	0.043	-0.524	0.127	-0.865	0.210	-1.200	0.291
CHM	-0.229	0.086	-0.681	0.257	-1.125	0.424	-1.560	0.588
NME	-0.140	0.142	-0.417	0.424	-0.688	0.701	-0.953	0.973
MET	-0.157	0.081	-0.466	0.239	-0.769	0.396	-1.066	0.549
MAC	-0.079	0.008	-0.233	0.025	-0.386	0.041	-0.535	0.056
CCC	0.141	-0.039	0.420	-0.115	0.695	-0.190	0.966	-0.263
OHM	-0.121	-0.055	-0.360	-0.165	-0.595	-0.272	-0.826	-0.377
ELE	-0.734	0.605	-2.161	1.801	-3.538	2.978	-4.867	4.138
CON	-0.006	0.021	-0.019	0.063	-0.032	0.104	-0.044	0.145
SER	0.059	-0.036	0.174	-0.106	0.285	-0.174	0.393	-0.240

On the whole, the imposition of environmental tax would result in the redistribution of factor endowments (labor and capital). When imposing the environmental tax, as labor force and capital can be transferred from the high-polluting sectors to the low-polluting sectors. Table 5 lists the percentage of changes in the labor force and capital input of various sectors. The sectors of electricity, livestock and fishery, wood processing and paper making/printing, food and tobacco are the top four sectors with the greatest decline of factor input. But the factor input for the electro-communication and instrument sector, machinery and equipment and service sector would be considerably increased. This is mainly because these sectors are of low-intensity pollution, which can absorb labor forces and capitals released by the dirty sectors to accelerate their own development.

Table 5. Results from simulations: changes in sectoral factor demand (%)

Sectors	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Labor	Capital	Labor	Capital	Labor	Capital	Labor	Capital
CCF	-0.097	-0.129	-0.291	-0.386	-0.483	-0.640	-0.674	-0.893
LSF	-0.195	-0.227	-0.581	-0.675	-0.962	-1.118	-1.337	-1.554
MIN	-0.128	-0.160	-0.382	-0.476	-0.630	-0.787	-0.873	-1.092
FOO	-0.150	-0.161	-0.447	-0.479	-0.740	-0.794	-1.030	-1.104
TEX	-0.073	-0.096	-0.223	-0.290	-0.377	-0.487	-0.535	-0.688
PPP	-0.175	-0.200	-0.517	-0.593	-0.852	-0.978	-1.180	-1.354
PET	-0.061	-0.089	-0.180	-0.266	-0.297	-0.439	-0.411	-0.609
CHM	-0.125	-0.157	-0.371	-0.466	-0.612	-0.768	-0.847	-1.066
NME	-0.034	-0.063	-0.100	-0.185	-0.162	-0.304	-0.221	-0.419
MET	-0.048	-0.079	-0.141	-0.236	-0.231	-0.388	-0.318	-0.537

MAC	0.037	0.015	0.111	0.045	0.184	0.073	0.255	0.101
CCC	0.340	0.314	1.013	0.937	1.680	1.552	2.339	2.159
OHM	-0.002	-0.033	-0.005	-0.100	-0.009	-0.166	-0.012	-0.232
ELE	-0.514	-0.545	-1.516	-1.609	-2.485	-2.639	-3.424	-3.637
CON	0.124	0.093	0.371	0.276	0.615	0.456	0.856	0.634
SER	0.146	0.114	0.433	0.337	0.714	0.556	0.991	0.769

The imposition of environmental tax would restrain the export of the emission-intensive products, and improve the export competitiveness of the cleaner sectors. Table 6 lists the percentage of changes in the import and export of various sectors in case of China's imposition of environmental tax. There is an obvious decline of export in emission-intensive sectors such as the livestock and fishery, mining, wood processing and paper making/printing, oil refining and processing, chemicals, non-metallic mineral manufacturing, metal smelting and product manufacturing, in which the higher the tax rate it is, the greater the export decline will be. It shows an obvious increase in the export of the electro-communication and instrument sector, service sector, which would increase by 2.1 and 1.4% respectively when the environmental tax rate are increased to eight times of the imposition standards of the current pollution emission charges. Since the imposition of environmental tax changes the domestic production structures, the changes of the domestic demand would lead to the corresponding changes in the import patterns.

Table 6. Results from simulations: trade patterns in China (%)

Sectors	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Export	Import	Export	Import	Export	Import	Export	Import
CCF	0.378	-0.368	1.127	-1.093	1.868	-1.804	2.600	-2.501
LSF	-0.520	-0.128	-1.547	-0.379	-2.557	-0.625	-3.550	-0.865
MIN	-0.293	-0.218	-0.868	-0.647	-1.432	-1.066	-1.984	-1.478
FOO	-0.159	-0.264	-0.478	-0.785	-0.797	-1.296	-1.116	-1.797
TEX	-0.125	-0.249	-0.381	-0.741	-0.644	-1.225	-0.912	-1.701
PPP	-0.628	0.065	-1.858	0.194	-3.055	0.321	-4.222	0.446
PET	-0.329	-0.119	-0.978	-0.353	-1.614	-0.583	-2.237	-0.809
CHM	-0.556	-0.107	-1.645	-0.318	-2.706	-0.525	-3.740	-0.730
NME	-0.690	0.028	-2.039	0.083	-3.347	0.138	-4.615	0.192
MET	-0.461	-0.055	-1.364	-0.163	-2.245	-0.269	-3.104	-0.373
MAC	-0.095	-0.068	-0.282	-0.203	-0.468	-0.334	-0.652	-0.462
CCC	0.313	0.047	0.933	0.139	1.543	0.232	2.146	0.323
OHM	0.118	-0.194	0.350	-0.575	0.574	-0.949	0.791	-1.314
ELE	-3.082	-0.006	-8.856	-0.023	-14.15	-0.046	-19.02	-0.075
CON	-0.074	0.014	-0.222	0.043	-0.368	0.071	-0.513	0.099
SER	0.219	0.006	0.648	0.017	1.065	0.027	1.472	0.037

5. Conclusion

In this paper, the GREAT-E model was used to assess the economy-wide impact of China's environmental tax reform. The simulation results show that the imposition of environmental tax is of very limited impact on China's macro-economy, in which the reduction in GDP can be made within the affordable range. Relatively, the emission reduction effect of the imposition of environmental tax on the pollutants is much greater than its negative effect on the economic development. The relatively higher rate of environmental tax could more substantially reduce the emission of pollutants. The imposition of environmental tax can increases the government income, but it would cause a certain adverse impact on the residential welfare. Due to the pollution emission reduction could improve environmental quality and lead to positive effects on residential welfare, the actual negative effect produced by the imposition of environmental tax would be in fact less than the simulation results.

The imposition of environmental tax would exert different influences on different sectors, in which the emission-intensive sectors would be restrained but the development of cleaner industries would, on the contrary, be accelerated. This is mainly because factor resources (capitals and labor forces) are released from these emission-intensive sectors and have been transferred into the cleaner industries, and promote the development of these industries.

In order to promote the internalization of environmental cost, it is suggested to raise the pollution tax/charge standard. Since the existing pollution charge standards are much lower the pollution control cost, many enterprises would rather pay the pollution charges than control the pollution. Therefore, tax rate should be at least equivalent to the pollution control cost when imposing the environmental tax in the future. Before the imposition of environmental tax, it is suggested to realize this goal by raising the existing effluent fee charge standards. In addition, it is proposed for the government to reduce the adverse impact induced by the imposition of environmental tax through relieving the income tax or providing subsidies to the vulnerable groups.

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