Economy and Environment Program
for Southeast Asia
22 Cross Street
#02-55 South Bridge Court
Singapore 048421
Tel: (65) 6438 7877
Fax: (65) 6438 4844
E-mail: eepsea@idrc.org.sg
Web site: www.eepsea.org

RESEARCH REPORT

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A Dynamic Computable General Equilibrium Analysis of Environmental Taxation And "Rural-Urban" Migration Distortions In China

Jing Cao
Harvard China Project, Harvard University Center for the Environment, Cambridge MA 02138, USA and School of Economics and Management Tsinghua University, Beijing 100084, China
email: Jing_Cao@ksg.harvard.edu; caojing@sem.tsinghua.edu.cn

This study investigates the potential impact of two environmental tax regimes on the movement of rural people to China's cities. The study models the impact of a fuel tax and an output tax on the country's economy to get a full picture of how they would affect people's livelihoods and welfare, and how this would, in turn, affect rural-urban migration. The study sheds light on the implications of future environmental taxes and how they would affect urbanization and "rural-urban" migration in China.

The study finds that both proposed taxes would discourage the flow of migrants from China's countryside to its cities. This would therefore exacerbate the current distortions in the country's labour market, where there is a surplus of rural labour. A comparison of the impact of the two taxes shows the fuel tax to be more efficient in terms of reducing pollution emissions and their associated environmental and health impacts. It also produces less distortion in the rural-urban migration process than the output tax. The study therefore recommends that this would be the preferable policy.

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A DYNAMIC COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS OF ENVIRONMENTAL TAXATION AND "RURAL-URBAN" MIGRATION DISTORTIONS IN CHINA

by

Jing Cao

April, 2007

Comments should be sent to: Jing Cao, John F. Kennedy School of Government, c/o Cruft 211B, 19 Oxford Street, Harvard University, Cambridge, MA 02138, USA. Tel: 1-610-742-0876. Fax: 1-617-384-8016.

Email: Jing_Cao@ksg.harvard.edu

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EXECUTIVE SUMMARY

For the past twenty years, the Chinese economy has achieved a growth rate averaging nearly 10% each year. However, this strong economic performance has been accompanied by severe environmental deterioration. To curb the rapid growth of air pollution, many environmental scholars are advocating an environmental tax policy, which has been extensively proved as an effective and efficient economic incentive instrument on pollution abatement by many OECD countries. However, a lot of literature on optimal environmental taxation in the "second-best setting" suggests that if labor market distortions are considered, an environmental tax policy will actually exacerbate pre-existing tax distortions in the economic system due to the negative "tax interaction effect", thus driving up welfare costs associated with environmental tax reform.

In previous literature on China's environmental tax policy, inelastic labor market assumptions were typically assumed due to the large labor force in China, giving rise to a strong form "double dividend" result (This suggests that environmental taxes can be used to discourage environmental damage activities and reduce the efficiency costs of pre-existing tax distortions simultaneously.) This result was obtained only when positive welfare gains from the "revenue recycling effects" were accounted for, while "tax interaction effects" in the labor market were zero due to the inelastic labor supply assumption.[1]

However, previous literature ignored the fact that in a transitional economy like China, because of the old household registration "*hukou*" system[2] and other government constraints on migrations, peasants' rural-urban migration behaviors are distorted and resulted in tremendous economic inefficiency in the allocation of labor resources spatially. Thus, there might be another type of "tax interaction effect" associated with the environmental tax in the second-best setting, which stems from the spatial allocation of urban and rural labor, i.e. migration, rather than from the entering or exiting behaviors in the labor market of western countries.

To bridge this gap, this study examines how environmental tax policies affect "rural-urban" migration flow and associated labor market distortions in China, using a recursive dynamic Computable General Equilibrium (CGE) model with two-representative households (rural vs. urban). This study analyzes the impact of two sets of environmental taxes: fuel tax and output tax and finds that both of these discourage rural-

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[1] The *revenue recycling effect* is the positive welfare impact from environmental taxation, if the tax revenues are recycled through cuts in marginal taxes of other pre-existing distortionary taxes, thus reducing the gross distortions or excess burden of the economic system (Terkla 1984; Lee and Misiolek 1986; Oates and Schwab 1988; Oates 1993; Repetto et al. 1992; Goulder 1998). The *tax interaction effect* suggests that environmental taxes would distort the factor market, the intermediate input market, or consumers' choices of goods consumption, and bring negative tax interaction effects to offset the positive revenue recycling effect (Bovenberg and de Mooij 1994; Bovenberg and van der Ploeg 1994; Bovenberg and Goulder 1996, 1997; Parry 1995, 1997; Goulder 1998).

[2] China's "*hukou*" system, which originated in 1951, requires citizens to reside in their birthplace. It strictly restricts the mobility of the population, including rural to urban migration.

urban migration flow and exacerbate the current spatial labor distortions in China. By comparing the two tax policy regimes, the CGE model simulations suggest that fuel tax is more economically efficient than output tax in terms of reducing more pollution emissions and associated environmental health damages, and bringing about lower distortions in the rural-urban migration process.

1.0 INTRODUCTION

For the past two decades of economic reform and opening up, the Chinese economy has achieved a high growth rate averaging nearly 10% per year, increasing per capita Gross Domestic Product (GDP) from 381 Yuan in 1978 to 14,040 Yuan in 2005, about nine times in real value terms.[3] However, like many other transitional economies during industrialization, China's economic growth is accompanied with severe environmental deterioration. According to the "State of the Environmental Report" in 2005 (SEPA 2005), only 4% urban cities satisfy Grade I of the national standard, about 56% in Grade II, and about 40% of the urban cities are in Grade III or lower. According to the World Bank, 16 out of the world's 20 most polluted cities are located in China, -- the air is so polluted it causes 400,000 premature deaths every year.[4] Based on a recent International Energy Agency (IEA) report (2006), China's carbon emission levels will surpass those of the US before 2009 to become the biggest contributor to global warming[5], almost ten years earlier than most people expected. With the rapid growth of automobile demand, urban air pollution is expected to be even worse in the next ten years. Currently, many environmental scholars are advocating the implementation of an economic incentive-based policy instrument, in particular an environmental tax policy to curb the rapidly growing air pollution in China. Now the question is: What would be the impacts of an environmental tax policy on China's economy? Surrounding this question is the hot debate on the "double dividend" hypothesis, which asserts that a green tax reform will not only improve environmental quality, but also increase non-environmental welfare (strong form) or at least lower the efficiency cost of the green tax reform (Bovenberg 1999). Recently some empirical CGE models suggest that the strong form "double dividend" hypothesis will hold in China (Garbaccio, Ho and Jorgenson 2000; Ho and Jorgenson 2007; Cao, Ho and Jorgenson 2005; He 2004).

However, a growing body of literature on optimal environmental taxation in the second-best setting suggests that if labor market distortions are considered, an environmental tax policy will actually exacerbate pre-existing tax distortions, the welfare gains from the revenue-neutral environmental tax reform might be lower and the "double dividend" hypothesis might not be valid (Bovenberg and de Mooij 1994; Bovenberg and van der Ploeg 1994; Bovenberg and Goulder 1996, 1997; Parry 1995, 1997; Goulder 1995,1998; Bovenberg and Goulder 1996, 2002). With the existence of a distorted labor tax, these literatures point out that the two general-equilibrium effects co-exist after the imposition of the environmental tax. The "revenue recycling effect" is the welfare gain

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[3] China Statistical Yearbook (2006)
[4] Hhttp://www.csun.edu/~vasishth/State_of_the_World's_Cities_2006_07.pdfH.
[5] World Energy Outlook 2006 (IEA, 2006)

by using the environmental tax revenue to replacing the more distortionary taxes such as capital and labor tax on factor income in the pre-existing tax system. The "tax interaction effect" is a welfare loss effect since the environmental taxes raise the price of the polluting goods, or in another sense raise the overall price level, resulting in a decline in real wages, thereby discouraging the labor supply in the "second-best world"[6] (Goulder 1995). Therefore, whether the "double dividend" hypothesis holds or not depends on the magnitude of the two opposing effects of the environmental tax. If the "revenue recycling effects" dominates the "tax interaction effect", then the strong form "double dividend" hypothesis will hold. Conversely, if "tax interaction effect" is larger, the strong form "double dividend" is absent.

Currently, the previous CGE models on environmental taxes in China all assume that the labor market as a whole is inelastic in China, and environmental tax reform will not drive distortions in the labor market. Therefore, only the welfare gains from the "revenue recycling effects" are accounted for and the "double dividend" becomes a common result.

However, there is another special type of labor market distortion which is widely ignored in previous CGE literature on environmental tax policies in China, that is, the spatial labor market distortions associated with the allocation of urban and rural labor, in particular the distortions associated with the current rapid rural-urban migration flow in China. Back in the 1960s, China had an old household responsibility system (HRS), which constrained rural residents to living in their birthplaces. But since the economic reform in 1978, there has been a dramatic increase in agricultural productivity, generating a huge labor surplus in the rural area – commonly characterized as a "push" factor driving the "rural-urban" labor flow. On the other hand, in urban areas, the expansion of the non-state sector, loosening of the urban employment policy, and the economic structure becoming more labor-intensive, have all created demands for rural migrants (Zhao, 2003). Williamson (1988) described this as providing labor flow for a "growing modern industrial complex", usually viewed as a "pull" factor for attracting migrant peasants to cities (Meng and Zhang 2001; Cai 2001; Williamson 1988; Zhao 2003). Sources suggest that the recent estimate about the temporary migrant "floating population" is about 19% of the whole rural population in 2001 (Zhai et al. 2003; Fan and Qie 2002). In modern economic theory, increasing urbanization and labor mobility are characterized as a momentum of economic transformation from an agriculture-dominated economy to an industrialized economy, increasing labor productivity for the society as a whole, thereby contributing significantly to China's rapid economic growth since its economic reform. It has been estimated that labor mobility and reallocation have contributed 16 to 20 percent to GDP growth since the initiation of the reform (World Bank 1996; Lees 1997; Cai and Wang 1999).

Following the idea of the "tax-interaction effect" in the enter-exit type labor market described earlier, we expect there might be a similar labor market distortion

[6] "Second-best world" is in contrast to the first best world, in which the environmental tax is the only tax in the economy, and an optimal first-best environmental tax is equal to marginal environmental damage (also called "Pigouvian tax"). In a second-best world where environmental tax is not the only tax implemented, environmental tax may interact with other taxes in a general equilibrium setting.

which stems from the changes in the spatial allocation of urban and rural labor forces, rather than from the entering or exiting behaviors in the labor market. However, more complicated than the distortions of labor supply in one labor market, examining the spatial labor market distortions with the two types of labor supply and allocations requires more complicated analyses. As we will discuss later, we decompose the effects of environmental tax into three mechanisms affecting the net migration flow from rural to urban areas. In terms of the general equilibrium effects, we cannot analytically determine the net direction of the three mechanisms. Thus we can only rely on numerical simulations to shed some light on the net effects of environmental taxation on the rural-urban migration process.

In this report, we formulate a recursive dynamic Computable General Equilibrium (CGE) model with two representative households (rural vs. urban) to examine the relationship between the proposed environmental tax policy and the spatial rural-urban migration distortions. Two environmental tax policies are selected for the analysis. One is fuel tax policy, a tax on primary fuels where the tax rate will be set as proportional to the average damage per unit of fuel use. The other one is output tax, a tax on sector output, where the tax rate is proportional to the marginal health damages of each sector. The goal of this study is to answer the following research questions: How would the "rural-urban" migration process be affected by the proposed environmental tax policy? Would the environmental tax policy exacerbate or relieve this type of labor market distortion? Which environmental tax policy is more efficient in terms of pollution reduction and impacts on the labor market?

The report is organized as follows. Section 2 firstly discusses an extension of Harris and Todaro's (1970) theoretical model on the "rural-urban" migration process and wage differentials. Based on this model, an empirical estimation of the determinants of rural peasants' migration decisions was made using micro-level data from the Chinese Household Income Project (1995), thus the empirical estimations could be used to calibrate the key migration equation in the CGE model. Section 3 gives a brief description of the recursive Chinese CGE model used in this study, the calculation of pollution emissions and health damages, and the modeling of rural-urban migration in China. Section 4 presents the base case projection and describes three base case scenarios on future migration processes. Based on the base case projections, Section 5 presents the results from the counterfactual fuel tax and output tax simulations. A sensitivity analysis of counterfactual simulations was conducted by allowing different levels of rural-urban labor mobility corresponding to the three migration base scenarios. Finally, in Section 6 the net effects of environmental tax policies on migration process are decomposed into three mechanisms, the results are interpreted, and caveats in the study are given with conclusions.

2.0 CHINA'S RURAL-URBAN MIGRATION AND WAGE DIFFERENTIATION

In this study, the migration process is modeled explicitly in the CGE model. To provide crucial parameters for this migration module, it was necessary to conduct empirical studies before the CGE modeling exercises. First, one needs to understand the theoretical aspect on rural-urban migration behavior and how it is related to the rural-urban wage differential. Then based on micro level survey data, an empirical analysis was conducted to estimate the key parameters in the urban-rural migration equations.

2.1 Theoretical Aspects of Rural-Urban Migration and Wage Differentials

Harris and Todaro (1970) developed a rural-urban migration model where individuals make decisions on whether to move to urban areas or stay in rural areas, depending on the wage differential of the rural and urban wage levels and unemployment levels. If a rational migrant peasant expects a higher wage income in an urban area compared with a rural area (i.e., the wage rate times the employment), he would move to the urban area. Here, our theoretical framework for modeling is just an extension of Harris and Todaro's simple model in an inter-temporal mover/stayer decision-making framework. Rural-urban migration decision can be derived from the optimizing behavior of migrant peasants, who treat the migration cost as an investment on their human capital, shifting from being unskilled to skilled. The more stringent the migration constraints or the household registration system regulations are, the higher the investment/migration transaction costs. The ownership of the land[7] and other psychological reasons will also increase the migration transaction costs. Equation 1 suggests that, an individual *i* migrates when his expected discounted utility stream $U(W_{ui}^e)$ in an urban area exceeds his expected utility stream by staying in a rural area $U(W_{ri}^e)$, after subtracting the total present value migration cost $C_{i,mig}$ (revised from Kinnunen 2000; and Hämäläinen and Böckerman 2002). W_{ui}^e denotes the expected effective wage income when a migrant peasant chooses to work in the city.

Equation (2) gives a simple calculation of W_{ui}^e, where λ indicates the probability of finding a job in urban areas, W_{ui} is the urban wage rate for the individual *i*. W_{ri}^e indicates the shadow wage of the migrant peasant's rural income if he chooses to stay.

$$\int_0^T (U(W_{ui}^e) - U(W_{ri}^e))e^{-rt}dt - C_{i,mig} \geq 0 \qquad (1)$$

$$W_{ui}^e = \lambda W_{ui} \qquad (2)$$

[7] Migrants' fear of losing access to agricultural land would also prevent them from leaving the land, even though the average shadow wage of agricultural production is much lower than the estimated effective urban wages.

The costs of migration $C_{i,mig}$ may include both direct and indirect costs of migration. Direct costs include transportation costs and payments to buy urban residence registration cards. The indirect costs include psychological costs such as being away from relatives in the original rural area (Zhao 1999) and other indirect migration costs due to the higher living costs in cities, such as higher expenditure for housing, limits to subsidized urban health services, children's education costs and so forth.

2.2 Empirical Research on Estimating Key Parameters in China's Migration Process

Due to the old household registration (*hukou*) system in China, people are confined to their birthplaces, and a large urban-rural income gap has developed. This *hukou* system has severely hindered China's urbanization process and created large "spatial"[8] labor market distortions with time. Since the 1990s, due to the Chinese government's relaxation on this long-standing migration control, China has begun to allow more labor mobility especially in recent years, and rural-urban migration has increased very fast and slightly mitigated the distortions in the migration process. However, the current income gap is still very large compared to other countries. Zhao (1999) documented an average annual wage gap between rural and urban work of 2,387 Yuan for unskilled rural workers in Sichuan in 1995. The per capita income in urban areas is about 2.5 to 3.1 times that in rural areas (Johnson 2002; NBSRG 1994). Sicular and Zhao (2002) empirically tested the effects of trade liberalization on levels of employment and earnings and estimated the household labor supply function. However, they did not model the rural and urban migration decisions specifically, thus it is difficult to incorporate their results directly in the CGE modeling used in this study. In the following section, a switching regression method is explicitly employed to estimate the determinants of rural peasants' migration decisions.

2.2.1 Data

In our empirical analysis, we use the Chinese Household Income Project (CHIP 1995[9]) data set from the Inter-University Consortium for Political and Social Research. The CHIP 1995 data set was collected by Carl Riskin, Zhao Renwei and Li Shi (2000); it was a joint research effort sponsored by the Institute of Economics, Chinese Academy of Social Sciences, the Asian Development Bank, and the Ford Foundation, with additional support provided by the East Asian Institute, Columbia University. This survey was selected from significantly larger samples (approximately 65,000 rural households and 35,000 urban households) drawn by the State Statistical Bureau.

The CHIP 1995 household survey data set is useful because it provides relevant information on rural peasants' migration behavior, personal income and hours worked in

[8] Here, "spatial" labor market distortions do not refer to real spatial migration from one region to another region, but the shifting between "rural" and "urban" categories only.

[9] In this study, we used the CHIP 1995 dataset. Although a later CHIP survey has been conducted, the dataset has not yet been made available to the public. The empirical work will be updated in a later version of this study, when more current data is available.

different occupations as well as a wide range of individual and household characteristics in both rural and urban areas of China.[10] In addition to the responses of migrants, we also learnt their work distribution in urban manufacturing sectors. For our estimations, we dropped individuals who did not answer the migration question on whether he/she would leave the household to work in other areas, so our sub-sample covered 7,500 households containing 21,127 working-age adults.[11]

Table 1 gives the descriptive statistics for the migrant and non-migrant workers for both male and female. This summary data foreshadows, to some extent, our estimation of the urban-rural migration decision-making. We find migrants' wage income is much higher than non-migrants. For male labor, the individual income is about four times of non-migrants; and for female labor, the migrants' income is about 12 times that of non-migrants. On average, the average income of migrant male labor is only 20% higher than that of female migrant labor, while the average income of non-migrant male labor is more than two times higher than that of female non-migrant labor.

Table 1 also suggests that migrants are younger than non-migrants for both male and female labor. In addition, migrants are better educated than non-migrants, and male workers have higher education levels than female workers. Among the male workers, the average duration of schooling is 7.35 years for migrant labor, with only 6.72 years for non-migrant labor. For female labor, the average education duration for migrant female labor is 6.82 years, about 1.8 years more than that of non-migrant female labor. In addition, single people tend to migrate, while married people are less likely to migrate.

Except for individual characteristics, household characteristics are also very important in explaining why peasants move. From Table 1, we find households with more land tend to stay in the rural area. If the migrant has a large household size, or he/she has more brothers or sisters, or he/she is the eldest, he/she is more likely to migrate to urban areas.

[10] Currently ICPSR data is available for two years, 1988 and 1995. In the 1995 data, it provides information on people's migration information, but in the 1988 data set, there is no migration information. So our study only relies on the 1995 cross-sectional data.
[11] We define working-age adults as individuals who are older than 15 years.

Table 1. Individual and household characteristics of migrants and non-migrants

Variable	Male		Female	
	Migrant	Non-migrant	Migrant	Non-migrant
Wage (*yuan* per year)	2,879	680	2,357	186
Age (years)	28.29	37.89	22.56	36.23
Years of Schooling	7.35	6.72	6.84	5.05
Dummy: Education Level				
Illiterate or semi-literate	0.01	0.05	0.03	0.20
Primary/elementary school	0.27	0.33	0.32	0.41
Junior middle school	0.57	0.47	0.57	0.33
Senior middle school and above	0.15	0.15	0.08	0.06
Dummy: Marriage Status (if married)	0.51	0.77	0.21	0.79
Total land size controlled by the household (*mu*)	7.34	7.98	7.71	8.07
Household Size	4.92	4.55	5.35	4.66
Number of Brothers and Sisters	1.49	0.63	2.23	0.58
Dummy: Eldest Status (if the eldest in the family)	0.37	0.19	0.42	0.11
Region Dummy Variable				
Beijing	0.02	0.07	0.01	0.07
Hebei	0.04	0.04	0.01	0.04
Shanxi	0.01	0.03	0.01	0.03
Liaoning	0.03	0.03	0.01	0.03
Jilin	0.07	0.06	0.02	0.07
Jiangsu	0.10	0.05	0.08	0.05
Anhui	0.09	0.04	0.14	0.04
Jiangxi	0.06	0.09	0.07	0.09
Shandong	0.06	0.09	0.06	0.09
Henna	0.02	0.05	0.03	0.05
Hubei	0.09	0.05	0.12	0.05
Hunan	0.14	0.09	0.14	0.10
Sichuan	0.03	0.04	0.05	0.04
Guizhou	0.01	0.05	0.00	0.05
Yunnan	0.04	0.04	0.02	0.04
Shannxi	0.03	0.05	0.00	0.05
Gansu	0.12	0.06	0.17	0.06
Guangdong	0.04	0.07	0.06	0.05
Number of Observations	**1,032**	**9,853**	**436**	**9,806**

Notes: This table summarizes the mean statistics of the survey data.
[a] Dummy: Dummy Variable is a numerical variable used in regression analysis to represent sub-groups of the sample. For example, dummy variable on marriage status = 1 if married, = 0 if not married.
[b] 1*mu* = 0.0667 hectares = 1/6 acre

2.2.2 Determinants of Rural Peasants' Migration Decision

Based on Harris and Todaro's extension model described earlier, urban-rural wage differential is an important factor in rural peasants' migration decision. In the CHIP 1995 data set, as in many labor economics studies, the problem of sample selection may arise, since the migrants' wage income is considered only if they had already migrated. So we apply the switching regression methodology introduced by Van der Gaag and Vijverberg (1988) and Zhu (2002) to address these kinds of econometric issues, and then analyze the impact of the income differential on migration decisions. We assume the migration selection process has two steps: first, an individual peasant will determine whether or not to migrate to obtain an urban job. Second, he/she may or may not obtain one in the urban area. He/she will compare the likelihood of the migration costs and risks of not having an urban job with the expected benefits. The probability of obtaining an urban job depends on individual characteristics, such as the migrant peasant's age, education level, geographic location, etc. Then the selection decision will be: an individual peasant will migrate if and only if:

$$(\ln w_u - \ln w_r) > \gamma Z + \varepsilon_1 \qquad (3)$$

where

w_u = the wage rate of migrant labor

w_r = the wage rate of non-migrant labor

Z = a vector of factors associated with the peasants' migration decision making

ε_1 = disturbance term

Similar to Van der Gaag and Vijverberg's (1988) approach to the selection process for public and private sector jobs, the above equation summarizes the two-step process: first, the expected urban-rural wage differential must be large enough so that peasants would like to migrate. Second, migrants have to face the selection process by the urban employers. Therefore, even if they migrate, they may still not be accepted by urban employers.

We assume that migrant wages and non-migrant wages are determined as follows:

$$\ln w_u = \beta_u X + u_1 \qquad (4)$$

$$\ln w_r = \beta_r X + u_2 \qquad (5)$$

where X is a vector of wage determining variables.

We now substitute equations (4) and (5) into equation (3) to get the selection rule (Equation 6):

$I = 1$ if $(\beta_u - \beta_r)X - \gamma Z + u_1 - u_2 - \varepsilon_1 = \beta' X + \gamma' Z + \varepsilon' > 0$ (i.e. peasant will migrate to an urban area)

$I = 0$ otherwise (6)

where I represents the migration decision, β', γ' and e' are coefficients in the reduced form equation. Assume the normality of all the disturbance terms e_1, u_1 and u_2, we can obtain the maximum likelihood of β_u and β_r. Note that ordinary least square (OLS) regressions on the migrant and non-migrant peasants are biased for OLS assumes that $\text{cov}(u_1, \varepsilon_1) = 0$ and $\text{cov}(u_2, \varepsilon_1) = 0$.

To solve this sample selection bias issue, we follow the three-step approach applied in Zhu (2002). Firstly, we estimate a reduced form probit function.

$$I = \beta' X + \gamma' Z + \varepsilon' \qquad (7)$$

where X is a vector of independent variables in the income equations and Z is a vector of independent variables in the selection equations. The result of the reduce form regression is presented in table 2.

Table 2. Determinants of the migration decision (reduced probit equation)

	Reduced Form Equation			
	Male		Female	
Age (years)	0.050***	(0.016)	0.020	(0.034)
Age square	-0.101***	(0.023)	-0.074	(0.053)
Education (years)	0.035	(0.024)	0.032	(0.032)
Education square	-0.002	(0.002)	0.000	(0.003)
Average household expenditure (*yuan* per year)	-0.00004***	(0.00001)	-0.00006***	(0.00001)
Land size (*mu*)	-0.011***	(0.004)	0.004	(0.005)
Dummy: Marriage Status (if married)	-0.208***	(0.067)	-0.762***	(0.116)
Household Size	0.089***	(0.017)	0.125***	(0.024)
Number of Brothers and Sisters	0.072***	(0.025)	-0.011	(0.030)
Dummy: Eldest Status (if the eldest in the family)	0.029	(0.046)	0.215***	(0.068)
Constant	-1.672***	(0.299)	-1.216***	(0.520)
Province fixed effects F stats	212.960 (P<0.0001)		200.970 (P<0.0001)	
log-likelihood	-2,943		-1,272	
Number of Observations	10,885		10,242	

Notes:
1) Dependent Variable: I = 1 if migrate, I = 0 if not migrate
2) The t-statistics are presented in parentheses:
* indicates coefficient significance at 10% level
** indicates coefficient significance at 5% level
*** indicates coefficient significance at 1% level

Second, we estimate migrant's income function and non-migrant's income function following the Heckman two-stage procedure to correct the sample selection bias (Heckman 1979). From the above reduced probit function, we can calculate the inverse mill ratio. Finally, we include the inverse mill ratio in the income generation functions as follows:

$$\ln w_u = \beta_u X + \eta_u \lambda_u + u_1 \qquad (8)$$

$$\ln w_r = \beta_r X + \eta_r \lambda_r + u_2 \qquad (9)$$

where λ_u and λ_r are inverse mill ratio calculated using $\lambda_u = \phi(X\hat{b})/\Phi(X\hat{b})$ from the reduced probit function (7). Table 3 shows the estimation of income equation (8) and (9) after sample selection adjustment for both male and female labor.

Table 3. Income equation after adjustment of sample selection bias

	Male		**Female**	
	Migrant	Non-migrant	Migrant	Non-migrant
Age (years)	0.074***	0.027**	0.095**	-0.027
	(0.020)	(0.011)	(0.038)	(0.018)
Age square	-0.100***	-0.026	-0.144**	0.036
	(0.032)	(0.017)	(0.063)	(0.023)
Education (years)	0.068	0.090***	-0.038	0.075*
	(0.052)	(0.030)	(0.074)	(0.041)
Education Square	-0.005	-0.005**	0.001	-0.003
	(0.004)	(0.002)	(0.006)	(0.003)
Average household expenditure (*yuan* per year)	0.00003	0.0001***	0.00001***	0.00009***
	(0.00002)	(0.00001)	(0.00003)	(0.00002)
Inverse Mill Ratio	-0.068	-0.121	0.026	0.033
	(0.219)	(0.177)	(0.215)	(0.148)
Constant	6.409***	5.581***	6.661***	6.055***
	(0.492)	(0.334)	(0.669)	(0.399)
R-square	0.142	0.126	0.170	0.117
Number of observations	908	3388	383	1099

Notes:
The t-stats are presented in parentheses:
* indicates coefficient significance at 10% level
** indicates coefficient significance at 5% level
*** indicates coefficient significance at 1% level

We find that income and age present an inverted U relationship, since age reflects the accumulation of human capital and social capital, for example, the accumulation of working experience and building up human connections, the so-called "*guanxi*" network in China. The age effect is much higher for migrants than non-migrants for both male and female workers. In addition, except for female migrants, income increases with education level, but the coefficients of education square are negative, so the marginal return on education is diminishing. But overall, the education effects are not statistically significant. Finally, we use county level average household expenditure as the proxy for the development level of the local area, thus we also have control for within-province difference. Finally we also have control for province fixed effects. From our regression, we find that if the local county average household expenditure is higher, the wage rates tend to be higher too.

Finally, we can recover the structural probit equation as Zhu (2002) did. From equation (8) and (9), we predict the migrant's urban wage $\ln \hat{w}_u$, and non-migrant's rural wage $\ln \hat{w}_r$. Then we can estimate the structural probit model, which includes the urban-rural wage differential as an independent variable on the right hand side in (10).

$$I^* = \varphi(\ln \hat{w}_u - \ln \hat{w}_r) + \gamma' Z + \varepsilon_1^{'} \qquad (10)$$

Table 4 shows the estimates of the impacts of urban-rural wage differential on migration decisions. Our results show that male and female workers have similar migration-wage elasticity, though it is slightly smaller for females. This result is quite different from Zhu (2002), who found that the migration-wage elasticity is about 1.38 for male workers and only 0.6 for female workers. Zhu (2002) applied similar switching functions to estimate the elasticities, but he used a small sample from only one province, Hubei province, in 1993. In contrast, our sample covers 17 provinces and the data was collected more recently in 1995. Zhu found the migration to be strongly selective, depending on the sex status. But we do not find evidence to support this argument. In addition, Zhu used per capita GDP as a proxy for regional development level. However, we believe using the per capita GDP data for a county level study is not appropriate, since the GDP data is usually collected at province level, so it is too aggregated to be treated as a proxy for local income. Therefore, we choose the county level average household expenditure to indicate within province variations on the wage determination.

Table 4. Determinants of migration decision (structure probit equation)

	Structure Form Equation			
	Male		**Female**	
$\ln \hat{w}_u - \ln \hat{w}_r$	0.749***	(0.161)	0.717***	(0.187)
Age (year)	0.022	(0.017)	-0.067**	(0.041)
Age square	-0.058**	(0.024)	0.056	(0.063)
Education (years)	0.055**	(0.024)	0.113***	(0.037)
Education square	-0.002	(0.002)	-0.003	(0.003)
Land size (*mu*)	-0.012***	(0.004)	0.004	(0.005)
Dummy: Marriage Status (if married)	-0.232***	(0.064)	-0.759***	(0.116)
Household Size	0.099***	(0.017)	0.124***	(0.024)
Number of Brothers and Sisters	0.080***	(0.025)	-0.011	(0.030)
Dummy: Eldest Status (if the eldest in the family)	0.032	(0.046)	0.214***	(0.068)
Constant	-2.585***	(0.309)	1.641***	(0.501)
Region Dummy fixed effects (F statistics)	127.42 (p<0.001)		73.87 (p<0.001)	
log-likelihood	-2943		-1271	
Number of Observations	10,885		10,242	

Notes:
1) Dependent Variable: I = 1 if migrate, I = 0 if not migrate
2) The t-stats are presented in parentheses:
* indicates coefficient significance at 10% level
** indicates coefficient significance at 5% level
*** indicates coefficient significance at 1% level

Since the elasticities for both male and female workers are positive, our results confirmed the Harris-Todaro theory through our empirical study. That is, if the urban-rural income differential increases, peasants are more likely to move. In addition, older male workers tend to be more likely to migrate to cities, probably driven by the responsibility and financial burden in raising a family. On the other hand, young women are more likely than older women to move. It might be the reason that the young women hope to save enough money from their urban jobs before they get married and settle down. Education level has a statistically significant positive effect on migration, since higher education increases the likelihood of getting an urban job in the labor market. Therefore, the expected returns from the migration would be higher than the expected migration costs. In particular the job searching costs will be less for higher educated workers. But the coefficients for the quadratic term are negative for both male and female workers; this might suggest that the marginal effects of the education level on migration are decreasing. Marriage status is also an important factor. Single people tend to move, while married people are more stable, preferring to stay at home due to family commitments such as the marital relationship, taking care of children and/or elderly parents and so on.

Furthermore, other household characteristics are important in the individual migration decision too. For example, the lack of land seems to be a driving force stimulating peasants to migrate to urban areas for jobs, while people who own land tend to stay for fear of losing it. In addition, if the household size is large, if the peasant has brother or sisters, or if he/she is the eldest child, the peasant is more likely to migrate.

3.0 THE CGE MODEL

A recursive Solow CGE model is applied to explore the inter-relationship between environmental tax reform and the rural-urban migration process. This model has been developed from the prototype Solow China model by Garbaccio, Ho and Jorgenson (2000), Ho and Jorgenson (2007). In this paper we updated the Social Accounting Matrix (SAM) table to the year 2000. In addition, we extended the one representative household assumption to two representative households (urban and rural) assumption. The summary of the structure of the CGE model is shown in Figure 1.

3.1 Overview of the Recursive Chinese CGE Economic Model

Our CGE model is calibrated to the 2000 SAM table, which was collected by Li Shantong and He Jianwu of the State Development Research Center in Beijing. Our model includes 33 industries, five production factors and two representative households (urban and rural). Among the factors, capital, labor, energy aggregate and non-energy aggregate are used by all the 33 sectors, while land is used only by agriculture, crude petroleum mining, and natural gas mining sector. Our urban manufacturing sectors include 5 mining sectors, 19 manufacturing sectors, 1 utility sector and 7 service sectors.

The summary of the characteristics of the 33 sectors and their pollutant emissions are shown in Table 5.

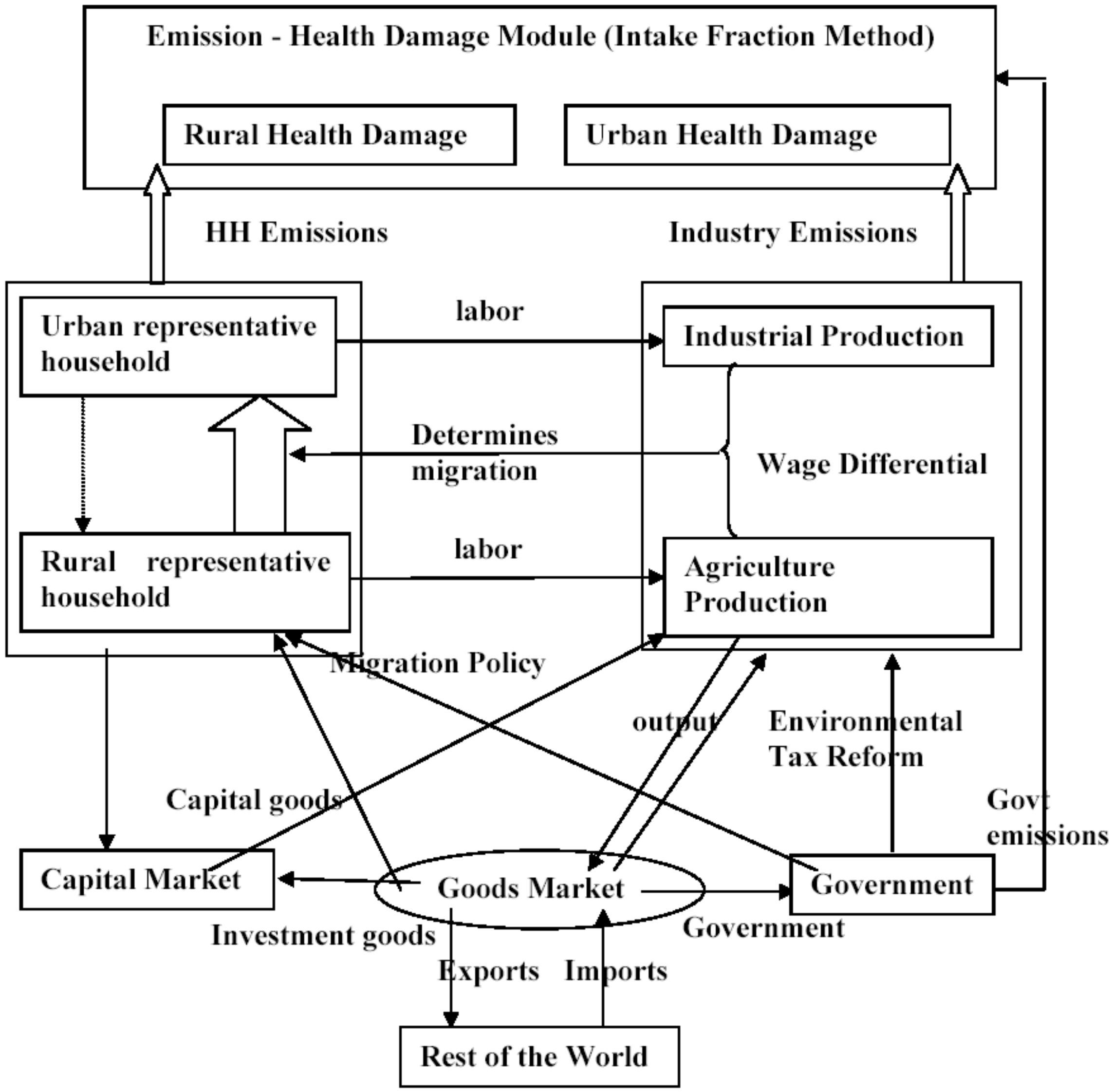

Figure 1. The Structure of the CGE Model of China

The setup of the USE and MAKE tables is the same as the US model in Jorgenson and Wilcoxen (1993) and recursive China Model in Garbaccio, Ho and Jorgenson (2000). The USE table represents the intermediate requirements for production. The inputs of industry *j* are represented in the j^{th} column of the USE table. Moreover, each domestic commodity group may consist of products from several industries, and this is represented by the MAKE table. The make-up of commodity *i* is represented by column *i* of the MAKE table. In our 2000 data, the MAKE table is fairly diagonal, thus most of the commodities are produced by the single industry, i.e., the only element of the column is the M_{ii} element. The flow of payments among various agents in the economy is summarized in the macro social accounting matrix (SAM) given in Table 6. Each row of the SAM represents the incoming receipts of industry, factor or institution. The corresponding column represents the expenditure or outflow of the sector, factor or institution. The sum of the row elements should be equal to the sum of the column elements, so that all SAM payments are balanced, and the incoming value and outgoing values for all sectors, factors, and institutions should be equal.

Structurally, the economic model is composed of production, household income distribution, consumption, investment, government revenue and saving, international trade, market equilibrium, and macro closure. Our model adopts a simple Solow growth model formulation to project future economic growth, which is driven by an exogenous savings rate s_t. From the 2000 input-output table, we calibrate the saving rate for the base year 2000 at about 25%. During our simulation years 2000-2030, we recognize the phenomenon that Chinese people are over-saving due to a variety of reasons such as lack of good social security, insurance and so forth. Therefore, we assume that the saving rate will steadily decline towards the end of our simulation year 2030, when we assume the saving rate at about 20%. To model the household demand on commodities, we use a Cobb-Douglas utility function form because we currently lack the micro-level household expenditure survey data to estimate for a translog function form of the demand function.

On the production side, we also assume Cobb-Douglas production functions. Like Garbaccio, Ho and Jorgenson (2000), we model a two-tier pricing system which allows for the fact that China is undergoing a gradual shift from a planned economy to a market economy. A fixed quota of output in each industry is sold at plan prices while output in excess of this quota is sold at market prices. Therefore, both planned and market allocation exist; this only creates a redistribution of profit between sectors, thus fixed output quotas are not binding, only infra-marginal. By modeling this two-tier pricing system, marginal decisions are based on market prices only rather than plan prices. The plan prices are exogenously modeled and are therefore just fixed parameters, changing over time according to our forecast of future market reforms. We do not model for optimal planned allocation, and plan prices are excluded from first-order conditions.

In our model, for simplicity, sectors are differentiated between rural and urban labor using a simple transformation function from unskilled to skilled labor, and we assume imperfect substitution between them. Urban labor is assumed not employed in agriculture, but perfectly mobile across non-agriculture sectors. Rural labor is assumed perfectly mobile across sectors, with about 82 percent employed in the agriculture sector. In our model, capital is assumed to be not perfectly mobile. It includes both fixed and mobile components.

Technology is characterized with constant returns to scale and labor augmenting. We assume that the production structure of China will resemble that of US in the future. As described in Garbaccio, Ho and Jorgenson (2000), the inter-temporal capital, labor, energy, land and material shares are assumed to gradually converge to the US input-output shares of year 1982 in about 50 years. The shares of coal, oil and gas in total energy costs are also expected to change with time, and roughly converge to the US energy share as well, except for an adjustment on the assumption that coal will still be the predominant energy source for the next 50 years. We also make exogenous time series projections on future population growth and the structure of age groups, public and current account deficits, world commodity prices, plan quantities and prices, plan capital, Total Factor Productivity (TFP) index of technology and so forth.

Table 5. Sectoral Characteristics for China, 2000

	Sector	Gross Value of Output (bil.yuan)	Estimated Capital Stock (bil.yuan)	Energy use (mil.tce)	Emissions (kton)	
					TSP	SO_2
1	Agriculture	2,645	1,194	40.3	136.9	297.1
2	Coal mining and processing	202	86	30.1	171.3	176.3
3	Crude petroleum mining	412	823	32.0	76.8	90.5
4	Natural Gas Mining	26	39	2.9	3.0	4.0
5	Metal ore mining	98	59	9.9	29.6	31.3
6	Non-ferrous mineral mining	140	111	15.6	26.6	28.8
7	Food products, tobacco	1,465	880	31.3	274.3	410.4
8	Textile goods	1,110	730	23.5	121.6	257.1
9	Apparel, leather	599	459	4.0	9.1	12.9
10	Sawmills and furniture	150	42	6.4	65.8	91.6
11	Paper products, printing	491	175	24.2	184.0	251.5
12	Petroleum refining & coking	794	369	334.0	211.7	307.7
13	Chemical	2,159	1,109	222.7	684.8	1,099.0
14	Nonmetal mineral products	628	523	119.7	10,665.7	2,338.5
15	Metals smelting & pressing	1,153	694	361.6	1,476.3	1,470.4
16	Metal products	420	250	23.4	123.3	73.1
17	Machinery and equipment	903	406	43.6	78.4	119.9
18	Transport equipment	1,016	502	22.1	36.4	52.2
19	Electrical machinery	987	478	15.0	21.2	28.3
20	Electronic & telecom. Equip	1,161	821	7.2	12.4	11.5
21	Instruments	97	56	1.4	2.3	3.1
22	Other manufacturing	182	307	7.8	139.9	182.8
23	Electricity, steam, hot water	852	2,119	468.6	3,037.7	7,199.6
24	Gas production and supply	38	16	37.1	90.2	70.5
25	Construction	2,216	643	77.4	204.3	628.9
26	Transport & warehousing	678	1,522	53.9	333.5	563.3
27	Post & telecommunication	380	1,324	10.1	0.1	5.6
28	Commerce & Restaurants	1,918	907	30.6	110.4	243.5
29	Finance and insurance	517	401	2.6	11.1	21.0
30	Real estate	296	1,989	7.4	78.1	134.2
31	Social services	808	1,236	31.8	207.6	405.6
32	Health, Educ., other services	883	1,228	39.0	359.6	615.4
33	Public administration	559	654	15.8	98.7	183.4
	Totals	25,979	22,152	2,239.9	19,082.4	17,408.9

Source: State Statistical Bureau Social Accounting Matrix for 2000; China Statistical Yearbook 2000, 2001, 2002, 2003; China Energy Statistical Yearbook 2000-2003; and author's estimate.
Notes: kton = 1,000 tons; bil. *yuan* = billions of *yuan*; mil tce = millions of tons of coal equivalent;

Table 6. Summary of Social Accounting Matrix (SAM) for China, 2000 (billion yuan)

	Commodity	Industry	Labor	Capital	Land	Urban HH	Rural HH	Enter-prises	Govt Subs.	Govt	VAT	Extra System	VAT Rebate	Assets	Row	Total
Commodity		17097.4				2369.9	1919.7			945.9		224.6	105.0	3250.0	2338.4	28250.8
Industry	26153.6	0.0														26153.6
Labor		4659.7														4659.7
Capital		2199.5														2199.5
Land		621.8														621.8
Urban HH			2851.9	0.0	0.0			300.9		234.0					48.1	3435.0
Rural HH			1803.9	0.0	529.0			23.0		17.9					3.7	2377.4
Enterprises				2082.1	92.9											2174.9
Gov. Subs.		-103.8								103.8						0.0
Government (other ind tax)		510.9				41.5	16.2	253.0			642.2			259.7	8.8	1732.2
VAT/Bus tax		642.2														642.2
Extra System		525.8														525.8
VAT Rebate										105.0						105.0
Assets						1023.6	441.5	1598.0		319.7		301.2			-174.4	3509.7
Row	2097.2		3.953	117.5						5.9						2224.5
Total	28250.8	26153.6	4659.7	2199.5	621.8	3435.0	2377.4	2174.9	0.0	1732.2	642.2	525.8	105.0	3509.7	2224.5	

Source: Social Accounting Matrix for year 2000 and author's estimates

For trade modeling, we take the usual Armington assumption. Domestic product is combined with imports to produce a composite good using a CES function. Exports are price sensitive, and determined by the exogenous current account balance and world price of commodities. Temporal accounting is observed. Investments accumulate into capital. Government deficits accumulate into a stock of public debt, and current account deficits accumulate into a stock of foreign debt. The public deficit is set exogenously and tax rates are calibrated from the 2000 input-output table. The current account balance and foreign debts are assumed exogenous in the model, merely to maintain accounting consistency, which play no role in the simulations. The government expenditures and tax revenues are endogenous, and determined by the size of economic activities. Although our single country model has strong assumptions on exogenous variables that would affect our base case simulation, the measured difference between the counterfactual and base case should be influenced only marginally.

3.2 Modeling Pollution Emissions and Health Damages

Environmental data is constructed to be consistent with the sector division framework, and total emission and energy use data are based on the China Environmental Yearbook, China Statistical Yearbook, China Energy Yearbook and China Energy Databook v5.0 and v6.0 (David *et al.* 2001; Sinton *et al.* 2004). In our model, we consider three kinds of pollution emissions: particulate matters (PM_{10}), Sulphur Dioxide (SO_2), and Nitrogen Oxide (NOx). In addition to the primary pollutants, we also include the secondary pollutants such as sulfates and nitrates. We assume the pollution emissions (EM_{jxt}) of pollutant x in sector j at period t are produced from the fuel combustion ($\sum_f (\psi_{jxft} AF_{jft})$) and non-combustion process in the production ($\sigma_{jxt} QI_{jt}$).

$$EM_{jxt} = \sigma_{jxt} QI_{jt} + \sum_f (\psi_{jxft} AF_{jft}) \quad (11)$$

$$\sigma_{jxt} = k_t^O \sigma_{jxt}^O + (1 - k_t^O) \sigma_{jxt}^N \quad (12)$$

$$\psi_{jxft} = k_t^O \psi_{jxf}^O + (1 - k_t^O) \psi_{jxf}^N \quad (13)$$

where

x = PM_{10}, SO_2, NO_X,

f = coal, oil, gas, and

j = sectors (1, …, 33, households)

Estimates of the base year combustion emission factor (ψ_{jxft}) and non-combustion emission factor (σ_{jxt}) are calibrated from the China emission data in the energy databook v 6.0 and the current 2000 SAM table. The time series emission factors are allowed to change throughout time, for simplicity we model the future emission factors as the weighted average of the current technology (denoted as O) and future new technologies (denoted as N), as given in equations (12) and (13). Thus future emission factors will gradually decline due to higher investment and more application of low-emission technologies.

Following the intake fraction method introduced in Ho and Jorgenson (2007), we take the intake fraction parameters estimated by the China Project, Harvard University Center for the Environment. The researchers in the China Project applied different scale air dispersion models to calculate the concentration change due to emissions from a large sample of smoke stacks in five cities in China. The industrial intake fraction studies had been conducted in China's most polluting industries – iron and steel, cement, chemicals, electricity and transportation. By repeatedly running air dispersion models many times, the intake fraction parameters were estimated by calculating the concentration change due to various height smoke stacks, geographic conditions, wind directions and speeds, local population distribution, breathing rate, real emission data collected, etc. Then the local sample intake fraction estimates by each industry were scaled to the whole country using simple adjustments recommended by Wang et al. (2007) and Ho and Jorgenson (2007).[12] Furthermore, Ho and Jorgenson (2007) take the average of their five sectors and applied this to the rest of the manufacturing sectors.

According to Ho and Jorgenson (2007), the intake fraction parameter (*iF*) is interpreted as "the fraction of emissions from a particular source that is actually inhaled by someone within the domain analyzed", which is given by:

$$iF_{xr} = \frac{BR\sum_{d} C_{xd}\, POP_d}{EM_{xr}} \tag{14}$$

where BR is the breathing rate, C_{xd} is the change in concentration at location *d* due to the emission of pollutant *x* in sector j - EM_{xj}, POP_d is the population exposed to the pollution at location *d*.

Emissions are calculated in our model simulation when we reach economic equilibrium, then using the estimated *iF* parameters, we can define the total dosage as the product of the *iF* parameters and the total simulated emissions (EM_{xjt}) from sector *j* at period *t* (15). Note in our simulation, since our data is updated using the projected population and composition, we also update our intake fractions every year. With the updated dosage estimation in each sector *j*, we can derive the health damages. Note in the traditional health damage estimation, health effects are calculated as the product of dose response parameters, concentration changes, and population exposed to the environmental pollution. Based on the definition of intake fraction parameters, we have $\frac{DOSE_{xj}}{BR} = \frac{iF_{xj} EM_{xjt}}{BR} = \sum_{d} C_{xd}\, POP_d$, so the product of $\frac{DOSE_{xj}}{BR}$ and the dose-response parameters DR_{hx} will give us the estimated health damages HE_{hj}^{S} (16). The final step is to

[12] In Wang et al. (2007), it is estimated that iF(infinity) exceeds iF(50km) by a factor of two or three. Following Ho and Jorgenson (2007), a simple adjustment is taken by multiplying the manufacturing industry iFs by a factor of three.

calculate the monetary value of the health damage TD_t, which is given by equation (17), where V_{ht} is the value of willingness to pay for each type health effect endpoint at period *t*.

$$DOSE_{xj} = iF_{xj}^{N} EM_{xj} = BR\sum_{d} C_{xd,j} POP_{d} \quad (15)$$

$$HE_{hj}^{IF,S} = \sum_{x} (DR_{hx} \frac{DOSE_{xj}}{BR}) = \sum_{x} (DR_{hx} \frac{iF_{xj}^{N} EM_{xj}}{BR}) \quad (16)$$

$$TD_t = \sum_{h} V_{ht} HE_{ht} \quad (17)$$

3.3 Modeling Rural-Urban Migration

In the numerical simulation literature, some models have explicitly included the migration component in the model. For example, Hoffman et al. (1996) modeled the interstate factor mobility in a regional model. Based on the Harris-Todaro model, Zhai and Wang (2002) applied a linear transformation equation to analyze the changes in rural-urban migration due to China's WTO entry. Kinnunen (2000) used the probability of population staying corresponding to the overall population levels to approximate the different levels of unemployment rates spatially.

From Harris and Todaro's migration theory and our empirical work on the wage differential between rural and urban labor, as well as the migration decision-making function, we can assume there is a periodic random job selection process from the combined pool of urban resident labor supply and rural migrants. For the migrant peasants, let us assume peasants have perfect knowledge on their expected wage rate W_{ut}^{e}, as described in equation (18).

$$W_{ut}^{e} = \frac{\sum_{j} Mig\_POP_{jt}^{e} W_{ujt}}{\sum_{j} Mig\_POP_{jt}} = \sum_{j} \varphi_j W_{ujt} \qquad (j = 1,2,...,33) \quad (18)$$

From the CHIP survey data, we have the information of how many people move to the urban area; and their distribution over the 33 industries if they got the job. φ_j is the distribution share of the number of the migrants working in the sector *j*, of the total number of migrants. For example, the CHIP 1995 survey shows that about 29% peasants working in the construction sector, 12% in trade and restaurants, about 37% in manufacturing sectors, and 4% in transportation and communication. Using these estimated share parameters, we define the base case parameter as $\varphi_j = \varphi_j^0$ for each sector *j*, which are directly extracted from our surveys.

However, in the counterfactual tax simulation cases, φ_j needs to be adjusted to allow for general equilibrium effects of environmental taxes. For example, some sectors might shrink due to the negative impacts from environmental taxes while other cleaner sectors might expand. Due to the general equilibrium effects and size changes of each sector, the labor demand of each sector will change, and the distribution of migrant workers will be affected, in particular in the manufacturing sectors. Therefore in our counterfactual case, we make a simple adjustment to calculate the average migrants' wage rate as follows:

$$W_{ut}^{e,C} = \varphi_{jt} W_{ujt}^{C} = \frac{\sum_j \varphi_j^0 \cdot \frac{LD_{jt}^C}{LD_{jt}^B} \cdot W_{ujt}^C}{\sum_j \varphi_j^0 \cdot \frac{LD_{jt}^C}{LD_{jt}^B}} \qquad (19)$$

where LD_{jt}^C is the urban labor demand of sector *j* in the counterfactual case, LD_{jt}^B is the urban labor demand of sector *j* in the base case, and W_{ujt}^C is urban wage rate of sector *j* in the counterfactual simulations. Under the assumption of constant returns to scale, if the size of the industry increases, the number of migrants hired in that sector will also increase proportionally.

In our recursive model, we recognize that wages are different among all the sectors, thus labor is not homogeneous and the productivity per worker, i.e., the equilibrium wage rate will vary from industry to industry. However, due to the optimal allocation of labor inputs across all industries, the marginal revenue product of labor per effective labor unit, i.e., the effective wage rate, should be the same under the assumption of perfect substitution. Considering that labor is heterogeneous across industries, we introduce a labor quality index ψ_j^{LD} which converts effective labor wage per labor unit to the real wage rate per worker. In our production function, we use equalized wage rate per effective labor units, thus the effective wage rate is the same across all industries, but the wage rates per worker vary depending on their labor productivity in that sector. The relationship between the real wage rate per worker W_j and the effective labor wage rate per effective labor unit W is as follows.[13]

$$W_j = \psi_j^{LD} \cdot W \qquad (20)$$

In our model, rural wage is modeled as the average wage rate in the rural area. Due to data limitation, we only have the value of labor inputs in each sector in the rural area, but we do not have quantity of labor inputs, thus we assume that in making migration decisions, peasants only compare their expected wage rate if they migrate with the average rural average wage rate, without further differentiating the rural wages by sector.

To simulate the migration process, a simple CET function is widely used to specify a "transformation" of rural labor into urban migrant labor (Eq. 21), i.e., from unskilled labor to skilled labor. Previous studies, such as Roland-Holst (1997) and Zhai et al. (2003) also use CET functions to model the relationship between migration and wage gap.

[13] Here the equation holds for both rural and urban labor.

$$\frac{L_m}{L_R} = \alpha(\frac{W_{ut}^e}{W_{rt}})^\gamma \tag{21}$$

where L_m is the number of migrant workers, and L_R is the number of rural workers working in the agricultural sector.

In our CGE model, for calibration purposes we revise the function form in equation (21), so that we can incorporate our empirical work to calibrate the key coefficients directly (Eq. 22).

$$\Pr(I = 1) = \frac{L_m}{L_m + L_R} = F(\alpha + \varphi \ln(\frac{\overline{W}_{ut}^e}{\overline{W}_{rt}})) \tag{22}$$

where $\alpha = \gamma' Z$ in equation (10) and function F is a cumulative normal distribution function. Based on the law of large numbers, the probability of rural workers migrating equals the ratio of $\frac{L_m}{L_m + L_R}$. In Table 4, we provided the estimation results of our structure probit equation on the determinants of migration decisions. Here, we use a constant parameter α to represent all the non-wage related factors (vector Z) such as age, education, marriage status, etc. Note that although these control variables are important, our variable of interest is φ. In our previous empirical work, we provided the estimation results on φ for both male and female workers. Since the SAM table used in this study only provides the aggregate data without sex classification, we use equation (23) to calculate the aggregate coefficient $\widehat{\varphi}$.

$$\hat{\varphi} = \hat{\varphi}_{male} \cdot Male\% + \hat{\varphi}_{female} \cdot Female\% = 0.749 \cdot Male\% + 0.717 \cdot Female\% \approx 0.734 \tag{23}$$

From the migration data in 2000, we find that about 27 million rural peasants migrated to the urban area, and the total agricultural labor is about 360 million. Thus, using this base year probability and calibrated parameter $\hat{\varphi}$, we can easily derive $\hat{\alpha}$. Using the calibrated parameters $\hat{\varphi}$ and $\hat{\alpha}$, we can bring equation (22) into the CGE model, thus we can measure the migration flow based on the urban migrants' and rural wage ratio. After we impose the environmental tax, the economy-wide effects will cause the variations in the urban vs. rural migrant wage gap, and eventually affect the equilibrium migration (Eq. 22).

Although there might be some crowding effects for the urban household, the current data shows that rural peasants actually enter informal sectors such as construction and service sectors or work as blue collar workers in industrial sectors, while the majority of urban households usually work in formal sectors or at different levels and are not easily replaced by the peasant workers. Therefore, we assume that crowding effects are very small and that the labor supply of urban households simply equals their labor endowments:

$$LS_{ut} = L_{ut} \tag{24}$$

The migration labor can be calculated as follows.

$$L_{mt} = LS_{rt} - L_{rt} \tag{25}$$

For the migrant rural peasants, the disposable income YD_t^m is:

$$YD_t^m = W_{ut}^e H_t - (DC_t + IDC_t) + DIV_t + G\_I_t + G\_transfer_t + R\_transfer_t - TAXN_t^{hh}$$
(26)

where H_t is the working hours of migrant labor, and the migrants' disposable income is calculated as the wage income and other incomes from the dividend income DIV_t, government interest payments on public debt to households G_I_t, government transfers $G\_transfer_t$, rest of the world transfers $R\_transfer_t$, deducted by the migration costs (direct costs DC_t and indirect costs IDC_t) and household lump sum taxes $TAXN_t^{hh}$.

4.0 BASE CASE PROJECTIONS AND SCENARIO DESIGNS

4.1 Base Case Projections

The base case is defined as a "business as usual" scenario, that is, without any environmental tax policy taking place. Our goal is to provide estimates of the *changes* in the urban-rural migration process, environmental damages, and economic performance due to the implementation of an environmental tax policy. Therefore, we need a projection of the future Chinese economy and future trend of rural-urban migration flow as the base case scenario. Our projections involve many simple assumptions, such as future population growth[14], technical progress and Total Factor Productivity (TFP) growth, changes in the household preferences, changes in the world economy and so forth. Although we made these exogenous assumptions, our central goal is to compare the base case and counterfactual cases. Therefore, we only have second-order effects on the percentage changes on the simulation variables of interests.

Since our data is based on the year 2000, we set it as our benchmark year for our base case simulation. The goal is to calibrate the first year of our model so that it can replicate the Chinese economy in the benchmark year. That is, all the key variables such as the labor force, capital stock, consumption, investment, import, export, and government expenditure, all match the real data in the input-output table of year 2000. After that, using the recursive structure of the Solow growth model, we run the CGE model repeatedly to simulate the Chinese economy in subsequent years. For each year, our model projects the output of all 33 sectors, the purchases of all intermediate inputs and factors, the consumption by urban and rural households, investment, government expenditure, exports, imports, and so forth. In this CGE model, the saving rate is set exogenously from 25% in the base year and then gradually declines to 20% in 2020. Thus household saving is exogenously determined and becomes the investment for the next period. Furthermore, in the subsequent period, capital stock will be updated from previous period investments, the labor force figure will be also updated from our projected future

[14] Projection Data Source: World Bank CHN data, http://devdata.worldbank.org/hnpstats

population, and the model will solve for all the equations again. In our model simulations, we repeat such a recursive process to model the future 30 years of Chinese economic growth.

Table 7 presents the simulation results of the main variables for the base case in the years 2000, 2010 and 2030. In our base case, GDP grows at an average rate of about 5.0% for the next 30 years. GDP growth is determined by the exogenous saving rate, overall TFP growth and so forth. We assume the growth rate will gradually decline over the next 30 years. By simulating the economy dynamically, our projection of the average GDP growth rate for the first 10 years is about 7.3% and 6.0% for the first 20 years. The projected GDP growth rate in this model is similar to other model forecasts, such as the 6.7% projected by the World Bank (1997) and 7.5% growth rate (2000-2010) by the Second Generation Model (SGM) used in Jiang and Hu (2001). The total population growth is projected at a slow 0.5% annual rate. However, due to the rapid urbanization and rural-urban migration process, the urban population rises very quickly at the annual rate of 1.33%. The rural population stays almost the same as the base year 2000, and in some years, there is even a very small negative growth.

Table 7. Selected variables from base case simulation

Variable	**2000**	**2010**	**2030**	**30-year growth rate**
Urban Population (million)	457	593	679	1.33%
Rural Population (million)	805	758	801	-0.02%
GDP (billion 2000 *yuan*)	9,128	18,430	39,180	5.00%
Energy Use (fossil fuels, million tons of standard coal equivalent)	1,213	2,075	3,115	3.19%
Coal Use (million tons)	1,232	2,066	2,992	3.00%
Oil Use (million tons)	209	375	602	3.59%
Carbon Emissions (million tons)	808	1,376	2,047	3.15%
Primary Particulate Emissions (m tons)	11.43	8.76	9.10	-0.01%
SO_2 Emissions (million tons)	19.26	26.24	35.54	2.06%
Nox (transportation) (million tons)	3.07	6.23	11.21	4.41%
Premature Deaths (1,000)	91	142	247	3.35%
Value of Health Damages (mil. *yuan*)	156	282	426	3.41%
Health Damage/GDP	1.71%	2.50%	3.50%	

In the base case, energy use is assumed to grow slower than the GDP growth, so that the energy-GDP ratio will decline over time. Among various energy uses, we assume oil use will grow slightly faster than coal use, about 3.59% in our simulations. The growth rates of coal use and carbon emissions are similar, ranging from 3.0% to 3.2%. As for particulate matters, we assume China will make substantial improvement in end pipe technologies to abate primary particulate matter emissions. So in our model, our assumed emission coefficients for new and old capital investment and future projections of coal share will decrease, while oil share will increase in the energy mix structure. This assumption results in a fall in particulate matter emissions in the first decade despite the increase in energy use (see Eqs. 11-13). After that, rising demands from the growth of energy use will dominate, and particulate matter emissions will rise again. Projected SO_2 emissions will rise much faster than particulates due to a less optimistic estimate in emission factors σ_{jx} and ψ_{jxf}. However, we still project some improvement in terms of sulfur emission abatement. For example, coal use rises at 3.0% per year while SO_2 emissions rise only at 2.1% over the 30-year period. The transportation sector is projected to grow rapidly and with it, NO_X emissions. Under our pessimistic assumption of only little improvement in NO_X emission factors, NOx emissions will grow at 4.41% per year over the next thirty years.

Our base case estimate of premature mortality is 91,000 deaths in 2000, and the average annual growth rate is about 3.4% for the next thirty years, which is slightly higher than the growth rate of energy use. The value of health damages grows at about the same magnitude as premature deaths, though slightly higher since the income elasticity of WTP is positive. The ratio of health damages to GDP indicates that health damages per capita national income would also rise quite rapidly from only 1.71% in 2000 to 2.5% in 2010, and 3.50% in 2030.

4.2 Forecast on the Future Rural-Urban Migration Flow and Scenario Design

In addition to the economy, energy use and environmental quality, we also need to project the future rural and urban labor market in the base case, thus we can have a baseline for comparing it with counterfactual tax simulations. We consider three base case scenarios. The first scenario is the "business as usual" scenario assuming that the Chinese government will keep the current moderate migration policy. Thus, we can forecast the future migration flow based on historical data. We also consider two alternative trends of future migration flow as well. For example, in the second scenario, we assume a lower rural-urban mobility which suggests that a stringent migration policy may take place. In the third scenario, we assume a higher rural-urban mobility which suggests that a loose migration policy may take place. The latter two cases are just for purposes of sensitivity analysis.

For the business as usual scenario, we forecast the future urban-rural wage differential based on the historical trend. Firstly, it is important for us to understand past migration evolution and its causes. Before the economic reform in 1978, the average migration rate in China was only 0.24, far below the world average of 1.84 from 1950-1990 (Zhao 2000). The people's commune system and "*hukou*" policy severely hindered the urbanization process in China (Zhao 2003). After 1978, the Household Responsibility System (HRS) emerged and greatly increased productivity in the agricultural sector, which generated surplus labor in the rural area. The surplus of rural labor in migration literature is often viewed as the main "push" factor that drives the rural-urban migration flow. Figures 2 and 3 give the historical trend of rural population, labor force and rural-urban migrants. Although since 1990 the rural population has stabilized and even declined after 1994, the rural labor force still increased very fast, for example the total number of workers increased by 14%, thereby creating a huge rural labor surplus. On the other hand, in urban areas, there were also "pull" factors in the rural-urban migration process, such as industrial economic reform and the development of special economic zones, the expansion of the non-state informal and service sectors, and the economic structure shift from capital intensive sectors to labor intensive sectors.

Both "push" and "pull" factors contributed to the increasing number of rural-urban migrants. Figures 3.3 and 3.4 show the historical trend of rural migrants from 1989 to 2000. In 1989, the migrants were only 8.9 million. This number almost tripled in 2000 to about 27 million. The "*hukou*" policy started in the 1960s and only relaxed very recently. From 1984 to 1988, the Chinese government started to allow rural workers to enter the urban areas on condition that they could provide food for themselves (Zhao 2003). Since the emergence of the "rural migrant wave" in 1989, the government interfered and restricted migration for fear that it would threaten the existing "*hukou*" system. After further rapid economic growth and increasing labor demand in the coastal cities in the early nineties, the central government began to relax its migration policy and to some degree, encourage the rural-urban migration, so we can see that the growth rate of rural-urban migration is very high for the period of 1989-1994, about 21% per year. From 1994 to 2000, due to pressure from layoffs and unemployment problems in the urban areas, the Chinese government started to tighten its control on the migration flow again (Zhao 2003). Thus the growth rate of rural-urban migrants declined to about 2.3% annually. In our business as usual scenario, we assume our future migrant flow will keep to an annual rate of 2.2% until 2030, about the same rate following the period 1994-2000. In Figure 4, we also give the future trend of rural migrants in the business as usual case, i.e. assuming that the Chinese government will sustain the current moderate migration policy.

Figure 5 shows the future trend of migration under three different labor mobility scenarios. We assume a 2.2% average annual growth rate of migrants in the business as usual scenario, a 2.7% average annual growth rate for a high labor mobility scenario, and a 1.5% average annual growth rate for a low labor mobility scenario. Thus, we can compare the counterfactual fuel tax and output cases with their corresponding base cases, under different labor mobility assumptions, and see how the imposition of new environmental taxes affect the whole economy, environment quality, and in particular, the rural-urban migration process.

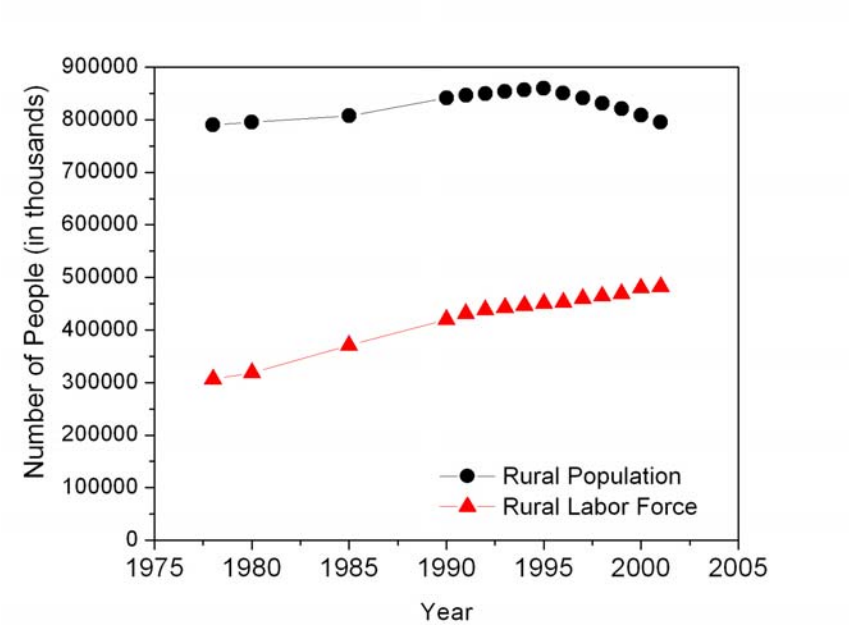

Figure 2. Rural population and labor force

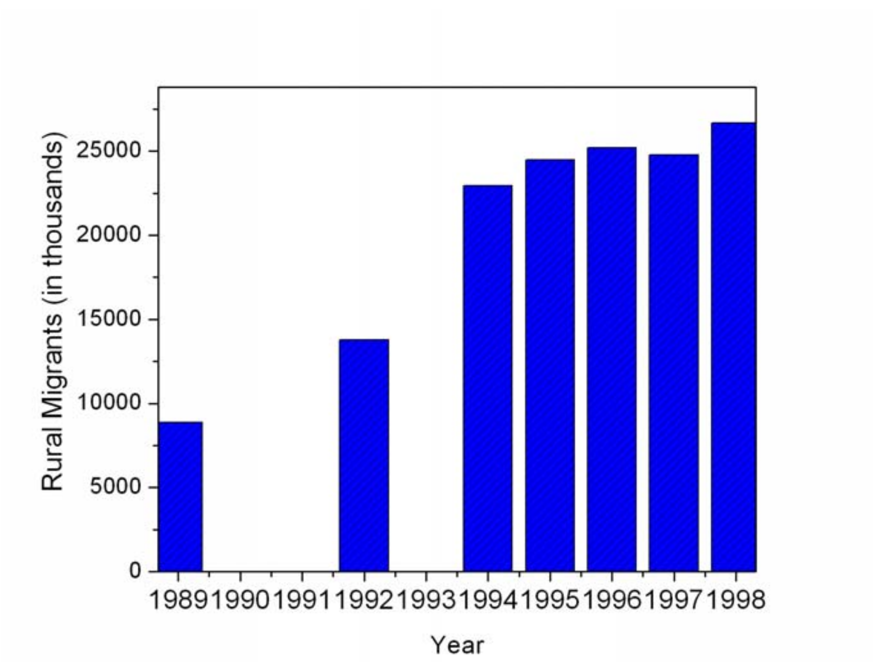

Figure 3. Rural-urban migrants (1989-1998)

Data Source: Zhao(2003), Table 1; National Bureau of Statistics of China (2002), Table 4-1, Table 5-4, Table 12-3; Sicular and Zhao (2002), Table 2.3.
Note: We do not have data on migrants for 1990, 1991 and 1993.

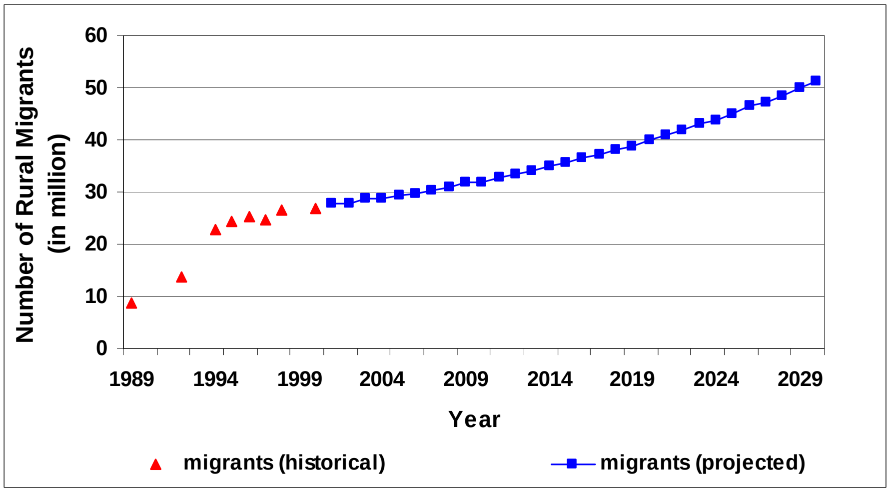

Figure 4. Forecast on future rural migrants

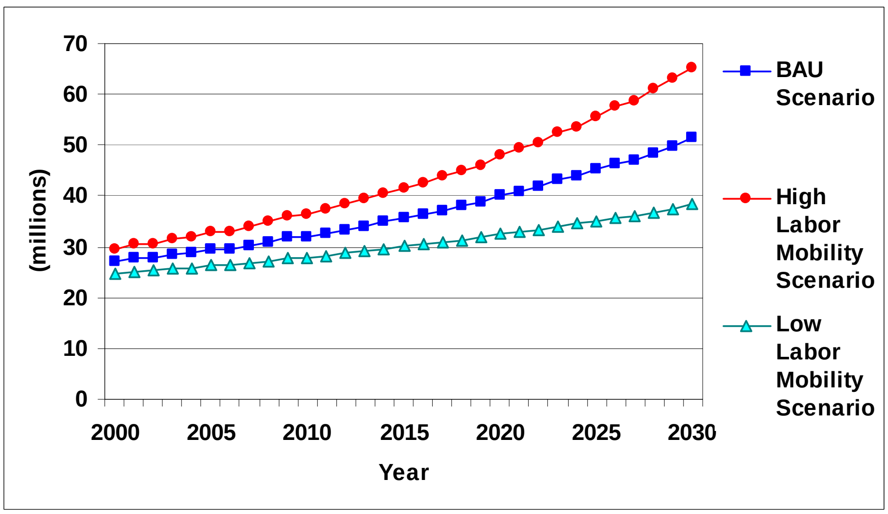

Figure 5. Projection of rural-urban migrants under three base case scenarios

5.0 SIMULATION RESULTS

In the counterfactual environmental tax simulation, similar to the tax policies proposed in Ho and Jorgenson (2007) and Cao, Ho and Jorgenson (2005), we examine two sets of environmental tax policies. The first is fuel tax, which is a tax on primary fuels, and the tax rate is set as proportional to the average damage per unit of fuel use. The second is output tax, which is a tax on sector output, and the tax rate is set as proportional to the marginal health damages caused by emissions released from the production of the commodities in each sector.

5.1 Fuel Tax Simulation

Although a ton of coal use in different sectors will produce different levels of emissions and damages depending on sectoral specifics, a sector-specific fuel tax does not seem plausible to implement. Thus in our model we assume an equal tax rate for the same type of fuel use in all the sectors, and the national tax rate is set as proportional to the average marginal damage per unit of fuel use (AMD_{ft}) over all the sectors (see Table 8). This will still cause producers to internalize the damages by choosing less fuel consumption or shifting to cleaner fuels.

$$AMD_{ft} = \frac{\sum_j MDF_{fjt} FT_{jft}}{\sum_j FT_{jft}} \qquad (f = \text{coal, oil, gas; } j = 1, 2, \ldots, 33) \qquad (27)$$

where AMD_{ft} is the average marginal damage of fuel *f*, MDF_{fjt} is the marginal damage of fuel use in sector *j*, FT_{jft} is the quantity of fuel use in sector *j* for fuel *f* at time *t*.

Table 8. Health damages from fuels, 2000

	Average Marginal Damage (AMD_{ft})		t_f^{xv}
	(yuan per unit fuel)		(*yuan* of damage per *yuan* of fuel)
Coal	108.62	*yuan*/ton	0.6754
Oil	64.56	*yuan*/ton	0.0143
Gas	0.50	*yuan*/1000m^3	0.0005

Source: author's own calculations

From Table 8, we can see that the fuel tax is mainly imposed on coal and oil use, while taxes on gas can be ignored since the damage per *yuan* of gas use is almost zero. Similar to the argument in Ho and Jorgenson (2007) and Cao, Ho and Jorgenson (2005), the damage rate for coal use is very high and a full tax equal to the average marginal damage per ton of coal use is unlikely to be adopted by the government, so we set a moderate 30% of their estimated health damage for our counterfactual fuel tax simulations here, i.e. $\lambda = 0.3$.

$$tf_{jt} = \lambda AMD_{ft} \qquad (j = \text{coal, oil, gas}) \tag{28}$$

The effects of the fuel tax on the economy, urban and rural wage rate, pollution emissions and associated health damages for the first and last year are given in Table 9. In our fuel tax simulation, the overall environmental tax burden is relatively small, only about 1.5-1.7% of the total tax revenue, thereby we expect the overall effect on the whole economy to be also very small. We find that the real GDP has a small decline at 0.01% in the first year. But the environmental tax has positive effects on the real GDP in the long run, for example, in the 30^{th} year, we find a positive impact of 0.01%. In our simulation, we assume a revenue neutrality here, which means when we impose a new environmental tax on fuel uses, we cut the other taxes, such as value added tax, capital income tax and sales tax proportionally to achieve the same tax revenue as in the base case. Since the capital income tax is cut in the counterfactual case, we can see there is a positive impact on the investment over the next 30 years. This is accompanied by a slight fall in real consumption of both urban and rural households, but the negative impacts will decrease with time. Similar to the results of Ho and Jorgenson (2007), since the fuel tax revenue is very small, the offsetting cuts for value added taxes and capital income tax are also small.

In our two-representative household model simulation, after the fuel tax, we find that the average migrant peasants' wage rate will decrease by 0.20% in the first year and 0.17% in the last year. The ratio of migrants' wage rate versus rural wage rate will decrease by 0.06% in the first year and 0.05% in the last year. From equation (23), we find that at equilibrium, the migrant flow will also decrease by 0.09% in the first year and 0.07% in the 30^{th} year. Thus, after the fuel tax implementation, we find the migration flow is reduced, although the impact is very small. In addition, the impact of the fuel tax on migration is smaller in the 30^{th} year than in the first year.

We now turn to the impacts of the fuel tax on environmental quality and health damages. After the fuel tax, from the simulation we can see that the industry structure and the choice of fuels will be significantly affected. The energy-intensive sectors will shrink as a whole after the fuel tax, and other sectors will relatively expand due to the equilibrium effects. Within each sector, there is an input substitution effect which reduces the value share of energy uses, or the whole energy structure shifts from coal use to oil use, or oil use to gas use. These effects will eventually reduce pollution emissions and associated health damages.

In our simulation, the total primary particulate matter will reduce by 6.4-9.3%. Sulfur dioxide emissions have a large 10.0-13.9% reduction. Due to the small tax on oil use, the NO_X emissions from transportation only decline by the rate of 0.6-1.2%. The large reductions in sulfur dioxide and primary particulate matters will generate a large reduction of 19.6-21.4% in premature deaths, and about 10.3-13.9% reduction in the value of health damages. The value of reduced damages accounts for a large 0.2-0.4% of GDP, compared to the base case total damages of 1.7-3.5% of GDP.

Table 9. Effects of fuel tax on the economic performance, rural-urban migration and health damages

Variable	**Effect in 1st Year**	**Effect in 30th Year**
Real GDP	-0.01%	+0.01%
Consumption (Urban Household)	-0.10%	-0.04%
Consumption (Rural Household)	-0.06%	-0.00%
Investment	+0.13%	+0.26%
Migrants' Wage Rate	-0.20%	-0.17%
Migrants'-Rural Wage Ratio	-0.06%	-0.05%
Migration Flow	-0.09%	-0.07%
Coal use	-12.90%	-17.30%
Carbon emissions	-10.26%	-13.20%
Primary particulate emissions	-6.38%	-9.27%
SO_2 emissions	-9.98%	-13.90%
NOx (transportation)	-0.58%	-1.15%
Premature Deaths	-19.60%	-21.39%
Value of Health Damages	-10.29%	-13.88%
Change in other tax rates	-1.91%	-1.80%
Reduction in Damages/GDP	0.18%	0.44%
Pollution tax/Total tax revenue	1.74%	1.55%

Figure 6 gives the impacts of fuel tax on sectoral output in the first year simulation. From this we can see how a fuel tax changes the size of different sectors through economy-wide general equilibrium effects. Since fuel tax is only imposed on fuel use, thus energy intensive sectors such as coal mining and process have the highest impact, and will reduce output by 13%; electricity, steam and hot water, and gas production and supply are also significantly impacted by reduced outputs of about 2%. On the other hand, there are only very tiny changes in all the other sectors.

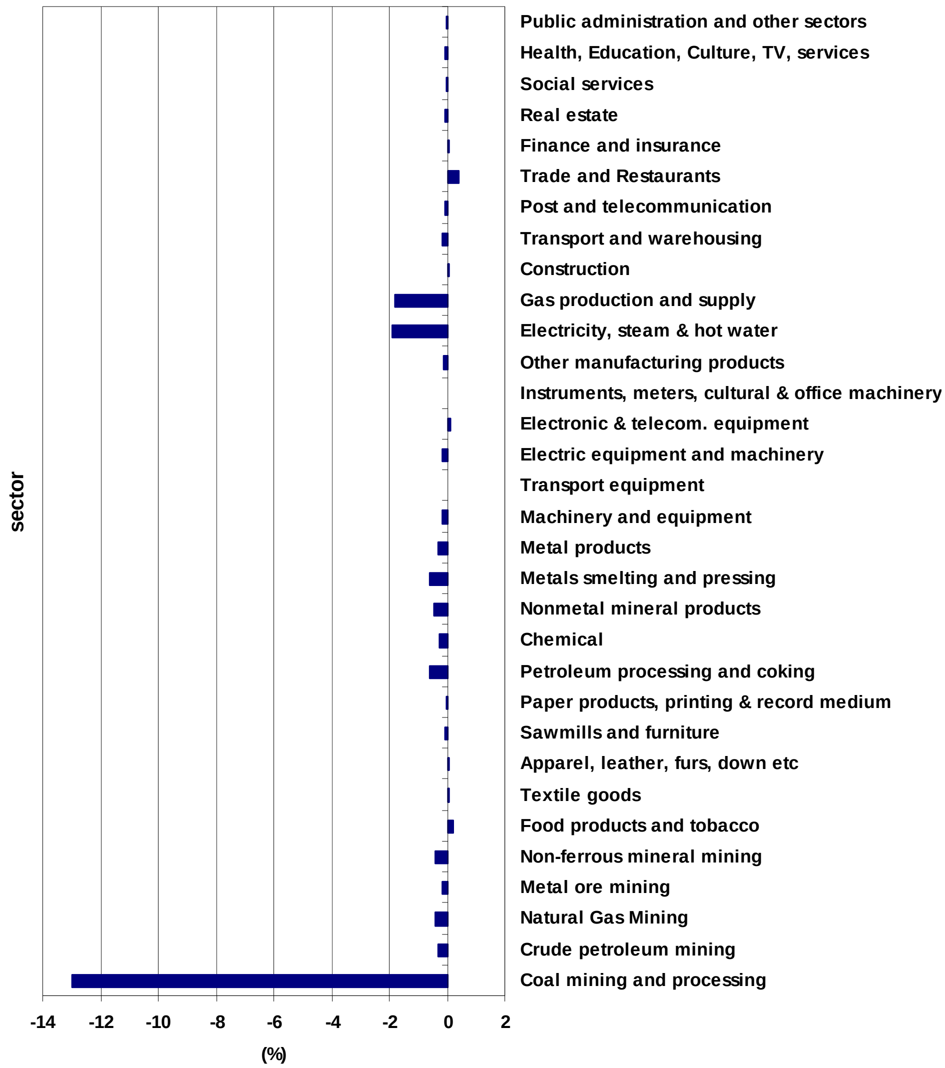

Figure 6. Impacts of fuel tax on sectoral output in the first year simulation

5.2 Output Tax Simulation

Our second policy proposal imposes a tax on the gross output of each sector, and the output tax rate is set in proportion to local health damages caused by the marginal unit of output. In our model simulation, as in Ho and Jorgenson (2007) and Cao, Ho and Jorgenson (2005), we assume a tax on output equal to the marginal damage (MD^O_{jt}) with $\lambda = 1$ (see Eq. 29). The marginal damage of PM_{10}, SO_2 and NO_x, and total marginal damages of all the 33 industries in the base year 2000 are presented in Table 10. We also provide the total environmental damages as well as their shares in the total damages in the last two columns. The output tax will increase the commodity price that internalizes the pollution externalities, thus consumers or intermediate input users will pay higher prices for products from the dirty sectors than for those from the clean sectors. Since the impacts are not directly imposed on the producers, the tax is not the most efficient, but in reality it is easy to implement for the state and local environmental agencies, since it produces smaller changes on prices and incomes, and the impacts will spread broadly to other sectors.

$$t_{jt}^{x} = \lambda MD_{jt}^{O} \tag{29}$$

Given the estimate of marginal damages for all the 33 sectors, the output tax only slightly increases the commodity price, for example, the electricity price increases by about 3.2%; for non-metal mineral products, by about 3.4%; and for metals, construction, and health, education, other service sectors, by about 0.6-0.8%. Table 11 gives the economy-wide effects of using these output taxes for the first and last years. Now we can see that the output tax has a positive impact on real GDP, although there is a tiny decline in the first year. The consumption of both urban and rural households increases in the counterfactual cases, rural households faster than urban ones. Different from the fuel tax, output tax has a higher impact on investment, starting from 0.2% increase in the first year to a very high increase of 2.0% in the last year, compared to base case simulations. This is due to the higher tax revenue collected from the output tax, about 7.6%-14.3% of total tax revenue, thus the “revenue recycling effect” is also larger than the fuel tax case.

In our output tax simulations, we find that the migrants’ wage rate will decrease by 0.77% in the first year and decrease by 1.44% in the last year. The ratio of migrants’ rural wage will decrease, about 0.45% in the first year and 1.03% in the last year. Based on our migration equation (22), at equilibrium, the migration flow will decrease by 0.60% in the first year, and by 1.37% in the last year. Therefore similar to the fuel tax simulation, in the output tax case, the migration flow will also be discouraged, but the impacts are larger than for the fuel tax case.

After imposing the output tax, the coal use will decrease by 3.5% in the first year and 10.2% in the last year. Similar to the trend of coal use, carbon emissions have smaller impact for about 3.0% decrease in the first year and 8.1% in the last year. The changes in the fuel use lead to a reduction in primary particulate matter emissions of 3.3% in the first year and 7.9% in the last year. The reduction of SO_2 emissions is similar to that of particulate matter, but has a larger impact in the 30th year. NO_X from the transportation sector is reduced by 3.1% in first year and 7.8% in the last year given a sizable output tax in that sector. We can see that, very different from the fuel tax case, the impact on the environment is quite small for the output tax case in the first year.

Table 10. Marginal sector health damage (yuan of damage per yuan of output), 2000

	Sector	Marginal Damage by Pollutant: Primary PM	Marginal Damage by Pollutant: SO_2, NOx	Total Marginal Damage Yuan /yuan	Value of Damages (mil yuan)	Share of Total Damages %
1	Agriculture	0.00003	0.00037	0.00041	1,076	0.72
2	Coal mining and processing	0.00334	0.00353	0.00686	1,673	1.12
3	Crude petroleum mining	0.00022	0.00037	0.00059	242	0.16
4	Natural Gas Mining	0.00002	0.00014	0.00016	4	0.00
5	Metal ore mining	0.00219	0.00199	0.00418	409	0.27
6	Non-ferrous mineral mining	0.00101	0.00176	0.00277	387	0.26
7	Food products and tobacco	0.00107	0.00167	0.00275	4,023	2.68
8	Textile goods	0.00060	0.00141	0.00201	2,229	1.49
9	Apparel, leather	0.00009	0.00014	0.00023	139	0.09
10	Sawmills and furniture	0.00115	0.00103	0.00218	326	0.22
11	Paper products, printing	0.00233	0.00407	0.00640	3,141	2.10
12	Petroleum processing & coking	0.00069	0.00037	0.00105	837	0.56
13	Chemical	0.00132	0.00278	0.00409	8,832	5.89
14	Nonmetal mineral products	0.01943	0.01343	0.03287	20,624	13.76
15	Metals smelting and pressing	0.00283	0.00314	0.00597	6,879	4.59
16	Metal products	0.00043	0.00097	0.00140	587	0.39
17	Machinery and equipment	0.00042	0.00056	0.00098	888	0.59
18	Transport equipment	0.00014	0.00033	0.00047	482	0.32
19	Electrical machinery	0.00010	0.00021	0.00031	310	0.21
20	Electronic & telecom. Equipment	0.00002	0.00009	0.00011	131	0.09
21	Instruments	0.00011	0.00021	0.00032	31	0.02
22	Other manufacturing	0.00014	0.00028	0.00042	77	0.05
23	Electricity, steam & hot water	0.00828	0.03829	0.04657	39,692	26.48
24	Gas production and supply	0.00166	0.00252	0.00418	158	0.11
25	Construction	0.00233	0.00146	0.00379	8,403	5.61
26	Transport and warehousing	0.00874	0.01266	0.02140	14,503	9.67
27	Post & telecommunication	0.00018	0.00009	0.00027	102	0.07
28	Commerce & Restaurants	0.00140	0.00068	0.00208	4,201	2.80
29	Finance and insurance	0.00044	0.00026	0.00071	365	0.24
30	Real estate	0.00714	0.00376	0.01090	3,229	2.15
31	Social services	0.00451	0.00271	0.00722	5,837	3.89
32	Health, Education, other services	0.00615	0.00322	0.00937	8,275	5.52
33	Public administration	0.00327	0.00187	0.00514	3,015	2.01
	Households				8,797	5.87
	Total				***149,904***	***100.00***

Table 11. Effects of output tax on the economic performance, rural-urban migration and health damages

Variable	Effect in 1st Year	Effect in 30th Year
Real GDP	-0.01%	+0.30%
Consumption (Urban Household)	+0.07%	+0.09%
Consumption (Rural Household)	+0.10%	+0.12%
Investment	+0.16%	+2.02%
Migrants' Wage Rate	-0.77%	-1.44%
Migrants'-Rural Wage Ratio	-0.45%	-1.03%
Migration Flow	-0.60%	-1.37%
Coal use	-3.45%	-10.19%
Carbon emissions	-2.95%	-8.10%
Primary particulate emissions	-3.32%	-7.89%
SO_2 emissions	-3.33%	-10.75%
NOx (transportation)	-3.08%	-7.78%
Premature Deaths	-2.95%	-5.84%
Value of Health Damages	-2.69%	-8.31%
Change in other tax rates	-7.57%	-7.95%
Reduction in Damages/GDP	0.05%	0.26%
Pollution tax/Total tax revenue	7.58%	14.30%

The effect of these reductions in both primary and secondary particulates is to lower premature deaths by 3.0% in the first year and 5.8% in the last year, and also to reduce the value of health damages by 2.7% and 8.3% respectively in the two years. The value of this reduction in damages in the first year comes to about 0.05% of GDP, and about 0.26% of GDP for the 30th year.

Figure 7 gives the impacts of output tax on sectoral output in the first year. Very different from the fuel tax, we see that many sectors are negatively impacted under the output tax. Therefore, it has a broader impact on the manufacturing sectors than fuel tax. Coal mining and electricity are still the most impacted, but in smaller magnitudes compared to the impacts under the fuel tax case. In addition, many other sectors such as transportation, non-metal mineral products, metals, chemical, and some service sectors are also more affected than in the fuel tax case. In particular, construction, transportation, and other manufacturing sectors, in which many rural migrants work, are also undergoing negative impacts.

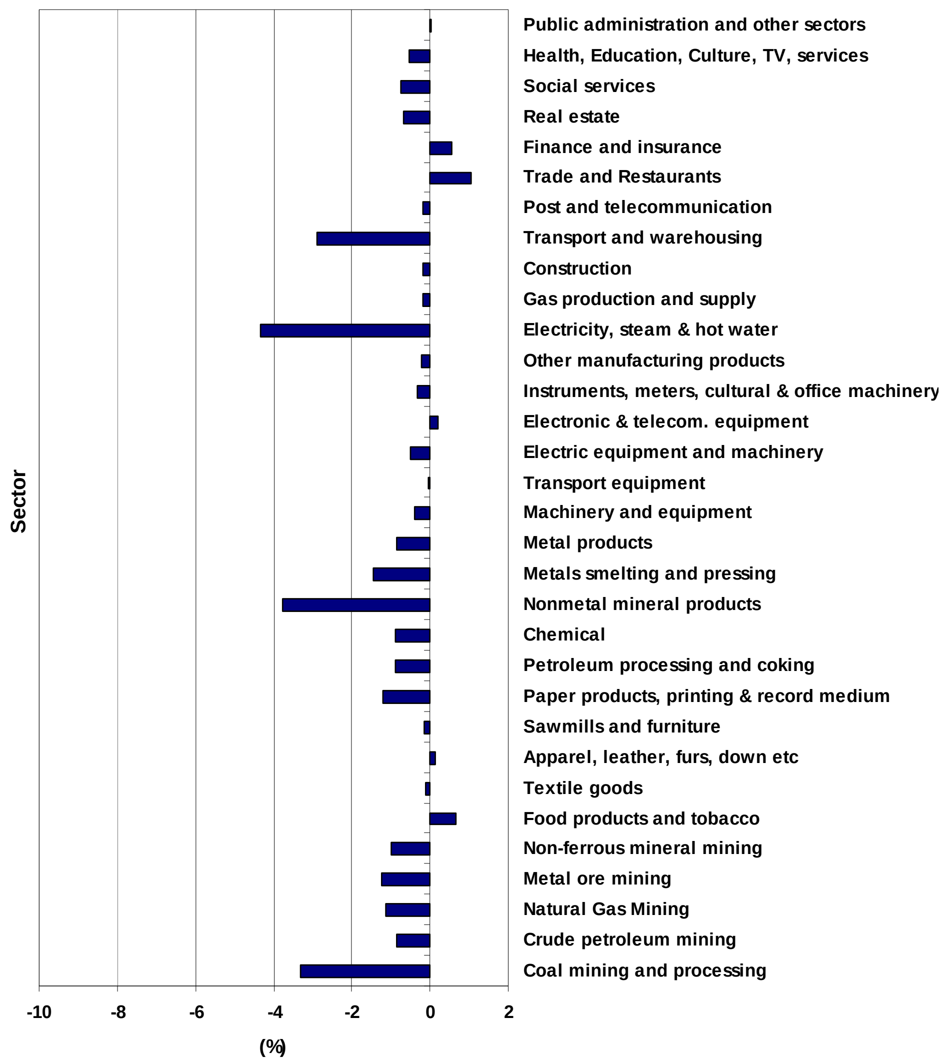

Figure 7. Impacts of output tax on sectoral output in the first year simulation

5.3 Sensitivity Analysis

We simulate fuel tax and output tax under three labor mobility scenarios. Figures 8-11 show both the absolute and relative changes in the migration population under the counterfactual taxation policy for different base case scenarios.

In Figure 8, for all the base case scenarios, we find fuel tax will actually discourage the migration flow as the absolute migrant population changes range from 0.02 million to about 0.035 million over the next 30 years. If we calculate the relative changes, i.e. the changes in migration population divided by the total migration population in different base case scenarios, we find the relative percentage change ranges from -0.1% to -0.05% (Figure 9). Comparing the absolute number of migrants and relative percentage changes, we find although the absolute changes increase over time, the relative impacts of fuel tax on the migration process gradually decline with time in the long run. Allowing for higher rural-urban labor mobility, we find the absolute change on the migration population is larger, but it is smaller in relative terms. Similarly, under the low rural-urban labor mobility scenario, the absolute change is smaller, but relative change is larger.

We also conduct counterfactual output tax under three labor mobility base case scenarios, and the results are shown in Figures 10 and 11. Similar to our fuel tax results, we find that the output tax will also have a negative impact on the rural-urban migration flow, ranging from -0.1 to -0.8 million population in fixed absolute terms, or -0.6% to -1.7% in relative percentage terms. Thus the relative change of output tax will increase over time, opposite to the fuel tax. The impacts of output tax are much higher than the fuel tax case. If we allow higher rural-urban labor mobility, also similar to the fuel tax case, we find the absolute change on the migration population is larger, but it is smaller in relative terms. Similarly, under the low rural-urban labor mobility scenario, the absolute change is smaller, but relative change is larger.

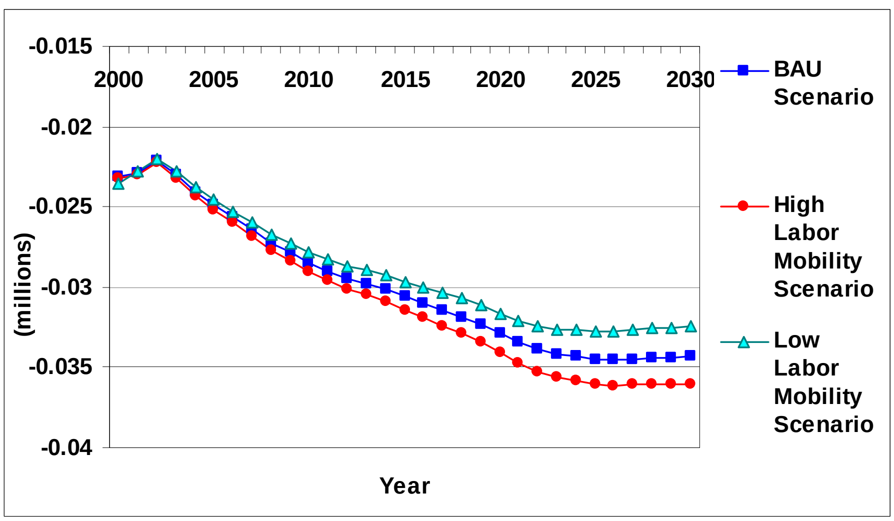

Figure 8. Absolute changes in rural-urban migrants of fuel tax simulation under three scenarios (Business As Usual (BAU), high labor mobility, low labor mobility)

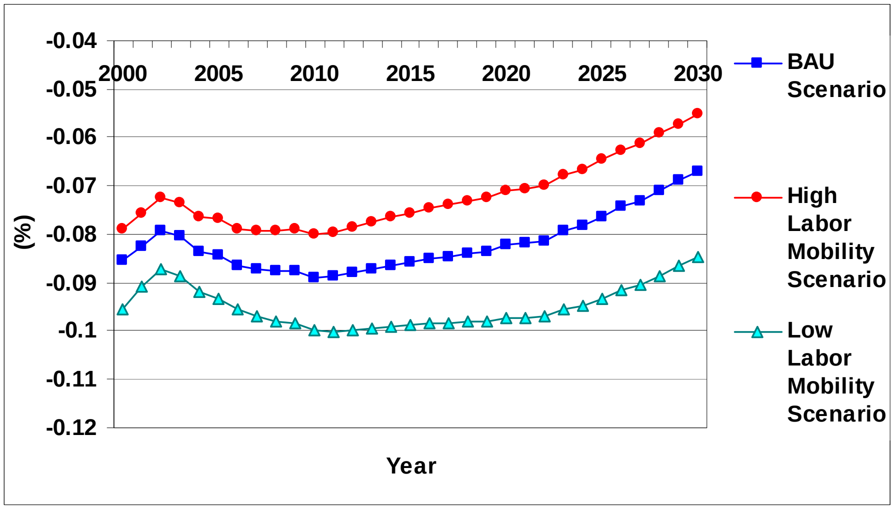

Figure 9. Relative changes in rural-urban migrants of fuel tax simulation under three scenarios (Business As Usual (BAU), high labor mobility, low labor mobility)

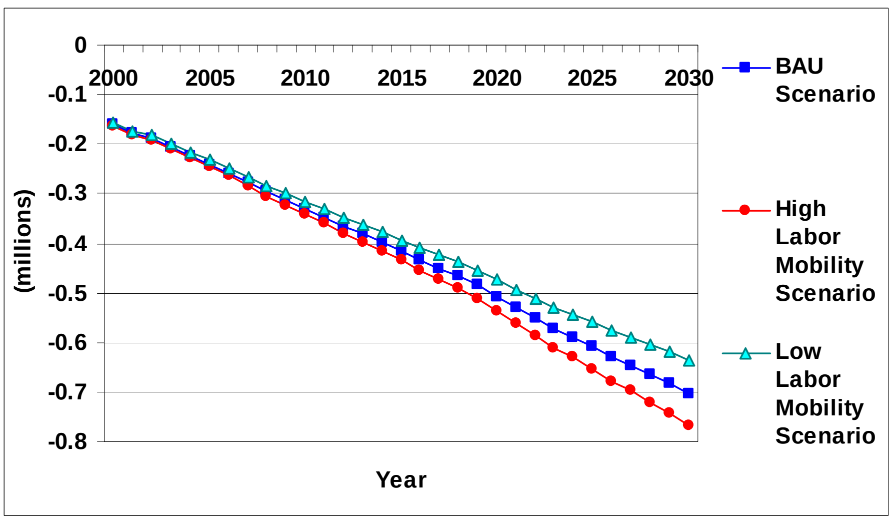

Figure 10. Absolute changes in rural-urban migrants of output tax simulation under three scenarios (Business As Usual (BAU), high labor mobility, low labor mobility)

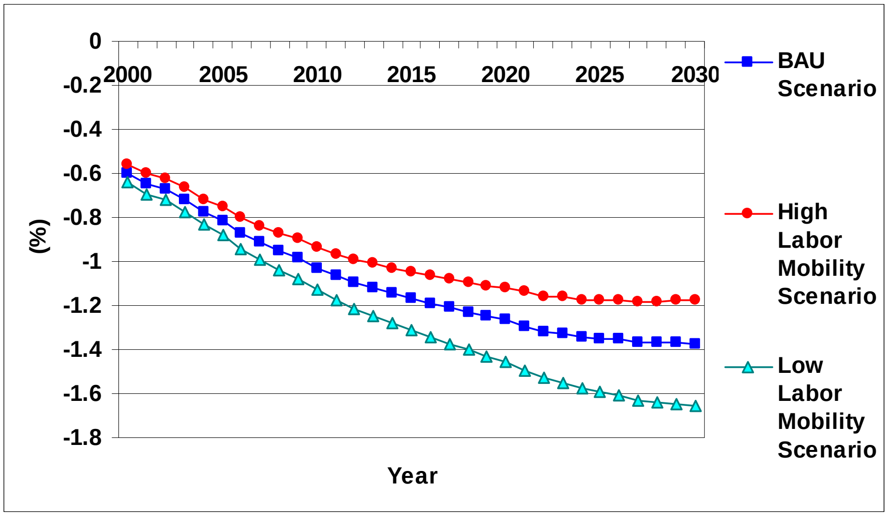

Figure 11. Relative changes in rural-urban migrants of output tax simulation under three scenarios (Business As Usual (BAU), high labor mobility, low labor mobility)

6.0 CONCLUSIONS

Since the adoption of economic reform and open-door policies introduced in 1978, China has experienced dramatic economic growth and rapid urbanization especially in the last two decades. On one hand, there is a rapid increase in agricultural productivity, generating a huge labor surplus in the rural area, the so-called "push" factor in the rural-urban migration flow. On the other hand, the expansion of non-state labor intensive sectors and industrialization has created a demand for rural migrants, becoming a "pull factor" to drive the migration flow. Due to these two primary reasons, the old household registration "*hukou*" system is gradually breaking down as more and more peasants flow into urban areas. The quantity of rural-urban migration almost tripled during the decade from the late 80s to the late 90s, whereby in 1989, the migrants were 8.9 million and in 1999, increased to 27.0 million (Zhao 2003; Sicular and Zhao 2002).

At the same time, China is experiencing increasing environmental pollution and associated health damages. To curb environmental pollution, the Chinese government is planning to implement economic incentive-based instruments, in particular, an environmental taxation policy. Western literature suggests that an environmental taxation policy might interfere with labor market distortions, thus creating negative "tax interaction effects" (Bovenberg and de Mooij 1994; Parry 1995; Goulder 1995; Bovenberg and Goulder 2002). However, unlike western countries, China currently has a very special labor market. As a whole, we can treat the labor supply as fixed, thus labor distortions will not arise from entering or exiting of the labor market as in the western countries. However, due to the government "*hukou*" system and recent relaxed migration policy, an environmental tax may interfere with spatial labor allocations, bringing about additional distortions to pre-existing labor market distortions, in particular in terms of rural-urban allocation inefficiencies.

To shed some light on this issue, we introduced a recursive dynamic two-representative household CGE model with both an environmental module and a rural-urban migration module to examine the counterfactual environmental taxation policy and the rural-urban migration process. Our simulations suggest that both fuel tax and output tax will negatively impact on the rural-urban migration flow, and the output tax seems to have a larger effect. To further understand the reasoning behind these simulation results, we can decompose the net effect into the following three mechanisms:

1) Industry Scale Partial Equilibrium Effect

First, let's consider the partial equilibrium world where the environmental tax policies only affect a single sector without interacting with other sectors through changes in the factor input markets and commodity markets. Since the energy tax is imposed on energy use, the rise in energy input prices will result in a substitution of labor for energy. In our CGE model, we assume Cobb-Douglas production functions, therefore labor inputs will increase and result in a decline in wages in those sectors. For output tax, in which case the tax is imposed on the output price, the relative factor price does not change, substitution effect is zero, thus in theory, wage rates will not be affected for the output tax case.

2) Revenue Recycling – Changes in Value Added Tax Rates

In our environmental tax policy simulation, we assumed a "revenue neutral" condition. This means that in order to keep total tax revenue fixed as the base case, we cut all other pre-existing taxes proportionally after we impose a new environmental tax. Thus the value added labor tax was deducted too, and resulted in an increase in the after-tax wage rate of all the rural and urban workers for both fuel tax and output tax cases.

3) General Equilibrium Scale Effects

In our migration module, we calculated the migration flow based on the wage gap between the migrants' wages and rural wages. In the counterfactual scenarios where environmental tax policies are implemented, we can use our CGE model to measure the economy-wide economic structural changes for each sector. For example, in the fuel tax simulation, we find that the energy-intensive sectors are highly impacted and may thus shrink in size, while other cleaner manufacturing and service sectors will expand. In the output tax simulation, the impacts were smaller for individual pollution-intensive sectors, but tax impacts were spread to many other sectors; thus the users of pollution-intensive outputs will need to pay higher commodity prices. In sum, due to these more complex general equilibrium effects, the impacts on migration flow cannot be predicted in analytical terms.

Therefore, because of the different directions and uncertain general equilibrium effects, it is difficult to identify the net direction of the urban wage rate relative to the rural wage rate analytically. Using our simple two-representative household CGE model, our simulations can shed some light on the overall effects of fuel tax and output tax. We find that both fuel tax and output tax decrease the wage gaps and discourage rural-urban migration flow. The impact of fuel tax is smaller than that of output tax on the migration process. From the partial equilibrium analysis, we know that the substitution effect would drive down the labor wage rate in the fuel tax case, while the substitution effect would be zero in the output tax case. We considered the impact of the reduction of value added labor taxes – both rural and urban after-VAT tax labor wage would increase, but the net impact on the ratio of migrants' rural wage gap would still be uncertain as we do not know the magnitude and so cannot determine the net direction. Considering the economy-wide general equilibrium effects, since we are focusing on the average migrants' wage rather than the average urban wage rate, the general equilibrium economic structure change and the base case distribution of migrants in manufacturing sectors together determine the net effects. In the output tax, the tax impacts are broader and many migrant-intensive sectors are negatively impacted, such as transportation, construction, and some service sectors. This might drive down the expected wage rate of migrants, while in the fuel tax case very few sectors are affected[15] and the general equilibrium effects will be small.

We also conducted sensitivity analyses for our environmental tax simulations under various labor mobility projection scenarios. We find that for both fuel tax and output tax, the absolute changes increased over time. However, in terms of relative percentage changes in migration compared with the base case scenario, the impacts of fuel tax on the migration process decline over time, while the impacts of output tax increase over time. For both fuel tax and output tax, for high labor mobility, the changes in the absolute number of migrants were larger, but the relative percentage changes were smaller compared with the business as usual scenario, and vice versa for low labor mobility; the absolute changes in the number of migrants were smaller, but the relative changes were larger.

Let us return to the discussions on the "revenue recycling effects" and the "tax interaction effects" in the second-best world, as well as the "double dividend" hypothesis debated in previous environmental tax literature. In our model simulations, we find strong "revenue recycling effects" in our counterfactual tax simulations; the effects are relatively higher than for the output tax policy. As for the "tax interaction effects", many Chinese CGE models ignored these by assuming an inelastic labor supply, thus the "double dividend" results would always hold due to the positive "revenue recycling effects".

Unlike previous Chinese CGE models and environmental tax simulations, however, we model a two-representative rural-urban household CGE model, and explicitly calculate the average migrants' wage rate to compare it with the rural wage rate in our simulations. We find that the wage differential decreased after the imposition of the environmental tax, resulting in a subsequent fall in the migrant flow to the industrial sectors. Most of the economic development and urbanization literature suggests that there is a welfare gain from a smooth urbanization process, so in other words, precipitating the rural-urban labor flow will reduce labor market distortions and improve economic efficiency. Based on this argument, our simulation suggests that environmental tax might

[15] In the fuel tax case, coal mining, electricity sectors are highly impacted, but very few peasant migrants are working in these sectors.

further distort this spatial labor market and migration flow process, and increase the deadweight loss. Therefore, it is important to incorporate these special effects into the assessment of the full economic costs and benefits for the environmental tax reform in China, and to revisit the previous "double dividend" results. Our model suggests that by imposing a moderate fuel tax and output tax as simulated in this study, the "tax interaction effects" are likely to be small, thus the "double dividend" would still hold.

Comparing the impacts of fuel tax and output tax on the economic system, environmental pollution reductions, and rural-urban migration labor market, we find that our preferred environmental tax policy would be a fuel tax policy, which will not only significantly reduce pollution emissions and decrease health damages, but also result in smaller rural-urban migration distortions. On the other hand, although output tax may be easy to implement and be more politically feasible, in terms of economic efficiency, a tax on the sales of output is less efficient in reducing emissions of either CO_2, PM or SO_2. This is because an output policy provides no incentives for firms to switch to cleaner fuels or to install scrubbers. On the other hand, in the output tax case, we find this tax will have more impact on the migrant-intensive sectors such as construction, transportation and some service sectors, greatly affecting the rural-urban migration process and thus creating higher "spatial labor market distortions".

Overall, our analysis illustrates how the CGE model can be a valuable tool for evaluating the effects of environmental policies on the economic-environment system as well as their impacts on the rural-urban migration process. However, several caveats should be mentioned. First, the model used here is a stylized simplification of the Chinese economy and we only modeled the migration process from rural to urban. We did not model the off-farm activities in the rural areas due to data limitations. Off-farm activities can be treated as lower transaction costs to the migrants, but the mechanism for them to shift from farming to other rural industries is exactly the same as for the rural-urban migration process. Thus, we would expect to get similar results. Secondly, our model does not model the detailed job searching process, but is based on a simple Harris and Todaro migration model. Finally, as in many other CGE models, numerous parameters in our model are calibrated on the base year observations of data, rather than using time series econometric estimations. Thus our results need to be interpreted with caution in terms of magnitude. However, our simulation results are indicative of the direction of the real effects.

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