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THE REGIONAL ECONOMIC EFFECTS OF A REDUCTION IN CARBON EMISSIONS AND AN EVALUATION OF OFFSETTING POLICIES IN CHINA

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DISCUSSION PAPER 12.14

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Abstract:

China has promised large cuts in CO_2 emissions by 2020, a policy which is likely to have differential effects across regions but we know little about the regional effects of pollution reduction. We make a contribution to filling this gap by using a small theoretical model with two regions, some features of the Chinese economy and the right to emit CO_2 as a factor of production. We find regionally differentiated effects of a pollution cut on income, welfare and output. We also explore government policies designed to reduce the effects of a carbon cut. The effects of fiscal policies depend crucially on whether one or both regions and on whether the focus is output or welfare are targeted. Boosts to productive capacity do better in terms of output but not welfare.

Key Words: carbon emissions, regional effects, numerical modelling, China
JEL classifications**: Q52, Q58, R12, R13**

1. Introduction

Global warming has been an issue of international concern. National governments across the world are subject to increasing pressure to reduce green-house gases (GHG), particularly carbon dioxide (CO_2) and China is no exception to this pressure. China's rapid recent economic growth has been accompanied by equally rapid growth of CO_2 emissions so that it has become the largest emitter in the world. Under the pressure from both international and domestic sources, the Chinese central government in 2009 promised to cut CO_2 emissions per unit of GDP by 40-50 per cent by 2020 compared with the 2005 level. It is almost certain that such drastic action will have significant consequences for the economy as a whole: there will be both a general increase in costs and a reallocation of activity from more-polluting to less-polluting industries. Moreover, such a policy will affect different regions differently – regions with an industrial structure which is heavily skewed towards polluting industries will suffer more than regions less reliant on polluting industries. These regionally differentiated effects are likely to be of important concern to Chinese policy-makers, given China's already large inter-regional disparities.[1] Yet, there is little analysis of the likely regional effects of a national reduction in allowable pollution.

This is not to say that the issue of the economic effects of pollution-reduction policy has been ignored. Indeed, the analysis of this issue goes back at least to the pioneering work by Nordhaus (1982), in which he points out that controlling the level of GHG emissions will have significant effects on production which need to be taken into account in designing the policy. In a subsequent paper, Nordhaus (1991) proposes a numerical model as a framework for evaluating the effects of GHG mitigation, after which many models have been developed for the analysis of the interaction between the economy and pollution-control.[2] These models

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[1] For an extensive discussion of regional heterogeneity and regional disparities, see Groenewold *et al.* (2008). For recent discussion, see Lin *et al.* (2011) and Sutherland and Yao (2011).

[2] See, e.g., Manne *et al.* (1995), Klepper and Peterson (2006), Nordhaus (1994), Nordhaus and Yang (1996), Nordhaus, (2010), Leimbach and Toth (2003), Tol (1997) and Hope (2006).

focus either on the world as a whole or on regions which consist of countries and study the effects of reductions in GHG on the world economy.

Despite this extensive array of models at the world level, there is not much work on the evaluation of the regional economic effects of carbon emissions reduction within a single country. There is a limited number of papers contributing to the theoretical analysis of this issue; Silva and Caplan (1997), Caplan and Silva (2005), Hadjiyiannis *et al*. (2009), Boucekkine and Germain (2009) and Hosoe and Naito (2006). In addition there are several studies which use large-scale computable general equilibrium (CGE) models; e.g., Adams (2007), Rausch *et al*. (2009) and Banzhaf and Chupp (2010). These models all have structures which closely mimic the economic structure of the economy being analysed and are calibrated using data for those economies. They all show substantial differences between the regional effects of centrally imposed policy; Adams, for example, generates regional output reductions ranging from zero to 2.5% across regions in Australia for a 21.1% reduction in emissions.

Turning to papers which focus on China, there are a few papers which develop CGE models to evaluate the economic effects of carbon emission reduction in China: Garbaccio, Ho and Jorgenson (1999), Zhang (2000), Fisher-Vanden and Ho (2007), Liang, Fan and Wei (2007), Aunan *et al*. (2007) and Liang and Wei (2012). However, all these papers focus on the effects of carbon emission reduction on macro variables for the country as a whole. None of them investigates the regional economic effects of emissions control, which is the focus of our paper. Our aim in this paper is to begin to fill this gap in the literature; we build on the literature but differ from it in the following ways.

First, we recognise that in the case of GHG reduction, the need to reduce pollution is increasingly likely to be derived from obligations under international agreements so that the immediate question and the focus of our paper is what the economic effects of such a reduction will be, in contrast to much of the pollution literature which is concerned with the design of an optimal policy response to emissions. In this sense, our paper is close to Zhang (2000) and Aunan *et al*. (2007) but we differ from them by analysing the effects of the policy on a range of economic variables across regions, not the country as a whole. While we focus on output and welfare at the regional level, we also include a discussion of the effects on other variables, such as relative prices, wages, profits, income and employment.

Second, we assume that, while the national rather than the regional government has the obligation under international agreements to implement pollution-control policies, both the national and the regional governments will be concerned about the possible adverse regional consequences of such a policy. It is likely, therefore, that the imposition of pollution-abatement measures will be accompanied by further policies designed to offset the expected adverse regional consequences of the pollution-reduction measures. Our paper extends the existing literature by considering the effectiveness of a range of such supplementary policies.

Third, given the questions we want to address, our model is distinct from existing ones. We build a simple two-region general equilibrium model based on the common distinction in China between the coast and the interior in which we include various aspects of the Chinese economy.

We analyse our model numerically, after linearising it and calibrating it with Chinese data. Strictly-speaking, this makes it a CGE model but it is several orders of magnitude smaller than most of the CGE models referred to above. This means that we cannot incorporate the detailed structures these larger models can and our numerical results cannot be considered “realistic” estimates of the likely effects on the Chinese economy. We are more interested in signs and relative magnitudes of the effects of shocks than in the magnitudes as such. Because of its small size relative to standard CGE structures, our model has the advantage that it is quite transparent so that we can easily trace the effects of policy through the model structure, something that it impossible in large CGE models.

The structure of the paper is as follows. In the next section we set out the model, followed in section 3 by the results. Conclusions are drawn in the final section.

2. The model

Our modelling strategy is to build as simple a model as is consistent with our objective. This allows us to preserve, as much as possible, the transparency of the way in which the model drives the results. This is in contrast to the CGE approach mentioned in the previous section. CGE models are generally very large (the Monash Multi-Regional Forecasting model used by Adams, for example, has 52 industries, 56 types of producers, 8 states/territories and 56 sub-state regions) with several consequent disadvantages: not surprisingly, the model cannot be set out explicitly in the paper reporting the results; instead, the reader is referred to supplementary documentation for the details of the model. Moreover, the mechanisms which drive the results are generally far from transparent, given the model complexity. In addition, the data required for calibration are more extensive the greater the disaggregation. This is particularly a problem when working on the Chinese economy for which detailed regionally-disaggregated data are sparse. Offsetting these disadvantages, however, the CGE approach has the benefit that the models generate numerical values at a very detailed level for many effects of pollution-abatement. Moreover, since they are carefully constructed to mimic particular economies, these numerical values are taken as projection of the effects of policies conditional on the assumed economic environment.

We use a closed-economy, two-region model. Ignoring the rest of the world naturally precludes the consideration of a number of interesting issues, particularly those relating to the strategic interaction between countries.[3] But considering a single-country model significantly simplifies the analysis. Given the focus of our paper on China and the common division of China into the coast and the interior, we call the two regions the coastal and inland (or interior) regions and denote them by C and I respectively. While we recognise that the regional structure of China is much more complicated than can be captured by this simple scheme, we note that these two regions have been the basis for the discussion of regional policy until at least the mid-1980s and, moreover, have been used in much empirical work on regional issues in China.[4] Despite the limitations, therefore, we use this two-region division in our model.[5] In the set of sensitivity tests reported at the end of the paper, we include an experiment with an alternative definition of the regions although this is still restricted to two regions.

Each region has households, firms and regional governments. There is also a central government. Households supply labour to firms which produce output. Households receive income from wages, profits and capital rental and they use this income to purchase some of each region's output; in addition, they receive a government-provided consumption good which is private in the rival sense.

Firms within a region produce a homogeneous output which differs across regions. We therefore talk of a single industry consisting of identical firms within each region. Firms use three conventional factors – labour, land and capital, as well as two additional factors: a government-provided public good which we call infrastructure and a factor, emissions permits, which allows us to introduce pollution into the model.

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[3] See, for example, recent papers by Wang *et al*. (2010) and Gavard *et al*. (2011) for the modelling of international interactions.

[4] Recent papers using this classification include Whalley and Zhang (2007), He *et al*. (2008), Fleisher *et al*. (2010) and Su and Jefferson (2012).

[5] In our numerical analysis below, the coastal region consists of Beijing, Tianjin, Hebei, Guangdong, Hainan, Shandong, Fujian, Zhejiang, Jiangsu, Shanghai, Liaoning and Guangxi with the remaining provinces being allocated to the interior region: Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Sichuan, Chongqing, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Tibet, Xinjiang.

There are various ways in which emissions might be modelled. First, they might be included in the utility function to reflect the disutility of pollution. This would be particularly important for addressing the question of the optimal level of pollution which would balance the benefits to utility of lower pollution against the extra production costs.[6] However, we do not deal with this question, but rather take the level of permitted emissions as exogenous. Besides, for the sort of policy environment which we have in mind, the benefits to households of lower CO_2 emissions are likely to be much more diffused over both time and space than the extra costs. This is exactly what lies behind the need for international agreements to limit CO_2 emissions. We, therefore, ignore the disutility of pollution.

On the cost side, the literature has incorporated pollution in two main alternative ways. The first is to assume that pollution produced is linearly related to output – see, e.g., Hosoe and Naito (2006).[7] The alternative, more general approach which we follow, is to treat pollution as a factor of production; see Beladi and Rapp (1993), Beladi and Frasca (1996), Rosendahl (2008), Hadjiyiannis *et al.* (2009) and Boucekkine and Germain (2009) for examples of this approach. We follow the second approach and assume that emissions permits are a factor of production which the firm must rent from the central government. We can think of this factor as the right to pollute or "environmental capital" in the sense of Hosoe and Naito (2006). Naturally, the number of permits (which we treat as an exogenous policy variable) also gives the level of pollution in the economy.

Both capital and emissions permits are inter-regionally mobile in the short run while labour, land and infrastructure are not. In the long run labour is also mobile between regions.

We distinguish between central and regional governments, with the latter including all sub-national government levels although we recognise that, in practice, the latter level includes several layers (provincial, prefecture, county and township). In our model, both

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[6] See Silva and Caplan (1997), Caplan and Silva (2005) and Banzhaf and Chupp (2010), for example.

[7] An interesting recent variation is in Silva and Yamaguchi (2010) in which a separate energy good is introduced which produces pollution 1:1.

levels of government provide households with a consumption good. The regional governments also provide infrastructure which is a public factor of production. We also include a transfer from the central to the regional governments.

On the taxation side, we assume three taxes in the model in a way which broadly reflects the stylised facts of the Chinese taxation system. The first is a national VAT, the rate for which is set by the central government at the same level for both regions and the proceeds from which are shared between the central government and the regions. The other two are regional taxes levied by each regional government on the output produced in its own region. In addition to tax revenue, the central government receives revenue from the rental of emissions permits to firms.

We assume that households supply labour inelastically to firms in their own region (each household supplying one unit) and choose consumption to maximise utility. Firms choose factor inputs and output to maximise profits, taking the factor prices as parameters. We assume that governments are exogenous but they need to satisfy their budget constraint.

We consider the behaviour of households, firms and governments in turn.[8]

2.1 Households

Households derive utility from the consumption of the two privately-produced goods (one produced by the firms in each region) as well as from a good supplied by governments. We assume a representative household in each region ($i = I, C$) and that the utility function for this household is of the constant-elasticity-of-substitution (CES) form:

$$(1) \qquad V_i = \beta_i(\gamma_{Ii}C_{Ii}^{-\rho} + \gamma_{Ci}C_{Ci}^{-\rho} + \delta_i GH_i^{-\rho})^{\frac{-1}{\rho}}, \qquad i = I, C$$

where V_i = utility, C_{ji} = real private consumption of good j ($j = I, C$), GH_i = real government-provided consumption, and β_i, γ_{ji}, δ_i and ρ, are parameters with $\beta_i > 0$, $0<\gamma_{ji}<1$, $0<\delta_i<1$,

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[8] A list of variables is given in Appendix 1.

$\gamma_{Ii} + \gamma_{Ci} + \delta_i = 1$, and $\rho > -1$.

Since we need to combine quantities of the two goods in order to formulate the household budget constraint, we find it useful to define a composite good which has a price index:

$$P_{COMP} = (P_I)^{\lambda}(P_C)^{1-\lambda}$$

where P_j is the price of good j ($j = I, C$) and λ is the share of interior output (indexed by I) in total output. We measure income in terms of the composite good, net of the VAT which we account for when we define income below.[9] Using P_{COMP}, the household budget constraint for region i can be written as:

$$(P_I C_{Ii} + P_C C_{Ci})/P_{COMP} = J_i$$

or, using the definition of P_{COMP} and letting P denote the price of I goods in terms of C goods, $P = P_I/P_C$, as

$$P^{1-\lambda} C_{Ii} + P^{-\lambda} C_{Ci} = J_i, \qquad i = I, C$$

where J_i= household income (net of VAT) in terms of the composite good in region i.

Utility maximisation subject to the household budget constraint gives the demand functions:

$$\text{(2a)} \qquad C_{Ii} = \frac{J_i P^{\lambda-1}}{P^{-1}(P\frac{\gamma_{Ci}}{\gamma_{Ii}})^{\frac{1}{\rho+1}} + 1}, \qquad i = I, C,$$

$$\text{(2b)} \qquad C_{Ci} = \frac{J_i P^{\lambda-1}}{P^{-1} + (P\frac{\gamma_{Ci}}{\gamma_{Ii}})^{\frac{-1}{\rho+1}}}, \qquad i = I, C.$$

Household income is derived from wages, profits and capital rental income. Households own a unit of labour each which they supply to firms in their own region, they own the capital in the economy as a whole in equal shares and they own the firms in their

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[9] The simple structure of the model implies that the VAT is equivalent to a tax on consumption and, given that households spend all their income, it is also equivalent to an income tax.

region in equal shares.[10] Wages, profits, and capital income are all measured in terms of output of the region in which they originate. Household income in terms of the composite good is therefore:

(3a) $(1+T_V)J_I = P^{1-\lambda}(\Pi H_I + W_I + R_{KI}K_I/L) + P^{-\lambda}R_{KC}K_C/L,$

(3b) $(1+T_V)J_C = P^{-\lambda}(\Pi H_C + W_C + R_{KC}K_C/L) + P^{1-\lambda}R_{KI}K_I/L,$

where T_V = the VAT rate, W_j = the real wage, industry j, ΠH_i = real profit distribution per household, region i, R_{Kj}= capital rental rate, industry j, K_j = capital stock industry j, and L= national population ($i, j = I,C$).

Inter-regional migration has been an important spatial equilibrating mechanism in regional models. In our model we allow for migration from one region to another, although given the slow reaction of migration to economic incentives, we allow for it only in the long run. Since the household registration system (*hukou*) is a prominent feature of Chinese internal migration, we include it in our model by assuming it increases the costs of migration where the cost of migrating from the interior to the coast increases with the population density of the coast, reflecting a greater resistance to further migrants from coastal residents, the more crowded the coastal cities become.[11] To simplify the analysis, we assume that migration occurs only from the poor to the rich region.[12]

In the models with free migration it is customary to assume that migration occurs until utility is equalised across regions. But under the *hukou* system, people will be worse off in the (poorer) interior since they will have to incur costs to obtain *hukou* for the coastal region. We therefore model the migration equilibrium condition as:

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[10] These assumptions help keep to a minimum the regional interrelationships while allowing for inter-regional capital mobility.

[11] See Liu (2005) for a general description and history of the *hukou* system.

[12] This avoids the discontinuities which result from two-way costly migration; see Mansoorian and Myers (1993) for an analysis of a model with such discontinuities and Woodland and Yashida (2006) for an approach similar to ours but applied to international immigration. Other authors such as Groenewold and Hagger (2007) have avoided the discontinuity by assuming migration to be costless but this is not consistent with the presence of *hukou* restrictions.

(4) $$V_C = \left[\frac{L_C / A_C}{L_I / A_I}\right]^{\mu} V_I, \ \ \mu > 0$$

where L_i is the population and A_i the area of region *i* so that L_i/A_i is the population density in region *i*; μ can be thought of as the *hukou* parameter– the larger is μ the greater will be the difference in utilities across the two regions (since the coastal population density exceeds that in the interior so that the term in brackets exceeds one).

2.2 Firms

We assume that there is a given number of firms in each region which, without loss of generality, we set equal to 1. Two goods are produced in the economy and it is assumed that firms in each region are completely specialised. We call the two goods interior and coastal goods according to the region in which they are produced.

In each region, firms use their fixed endowment of land, hire labour from households in their own region and capital from households across the country, emissions permits from the central government and combine them with government-provided infrastructure to produce output. Production technology is assumed to be Cobb-Douglas with constant returns to scale:

$$Y_j = B_j (LAND_j)^{(1-\alpha_{Lj}-\alpha_{Ej}-\alpha_{Kj}-\alpha_{Gj})} \left(L_j\right)^{\alpha_{Lj}} (E_j)^{\alpha_{Ej}} (K_j)^{\alpha_{Kj}} (GRF_j)^{\alpha_{Gj}},$$

$$0 < \alpha_{Lj}, \alpha_{Kj}, \alpha_{Ej}, \alpha_{Gj}, (1-\alpha_{Lj}-\alpha_{Kj}-\alpha_{Ej}-\alpha_{Gj}) < 1, \quad j = I, C$$

where L_j = employment, E_j = pollution emission permits, K_j = capital used, and GRF_j = infrastructure provided by the regional government, all for industry *j*.

We can simplify by writing: $D_j = B_j (LAND_j)^{(1-\alpha_{Lj}-\alpha_{Kj}-\alpha_{Ej}-\alpha_{Gj})}$ so that:

(5) $$Y_j = D_j \left(L_j\right)^{\alpha_{Lj}} (E_j)^{\alpha_{Ej}} (K_j)^{\alpha_{Kj}} (GRF_j)^{\alpha_{Gj}},$$

$$0 < \alpha_{Lj}, \alpha_{Kj}, \alpha_{Ej}, \alpha_{Gj}, (1-\alpha_{Lj}-\alpha_{Kj}-\alpha_{Ej}-\alpha_{Gj}) < 1, \quad j = I, C$$

The firms maximises profits (measured in terms of its own output):

(6) $\Pi F_j = (1-T_j)Y_j - W_j L_j - R_{Kj}K_j - R_{Ej}E_j, \quad j = I,C$

where T_j is the tax levied on output produced by industry j by the government of region j and R_{Ej} is the emission permit rental rate in region/industry j. Profits are maximised with the wage, the output tax rate, the capital rental rate, the emission permit rental rate and the supply of government infrastructure taken as given so that profit-maximisation implies the usual marginal-productivity conditions:

(7a) $\alpha_{Lj} Y_j (1-T_j) = W_j L_j, \quad j = I, C,$

(7b) $\alpha_{Kj} Y_j (1-T_j) = R_{Kj} K_j, \quad j = I, C,$

(7c) $\alpha_{Ej} Y_j (1-T_j) = R_{Ej} E_j, \quad j = I, C.$

All factor markets clear. On the labour supply side, each household is assumed to provide one unit of labour to the firms in its own region. We assume that wages adjust to clear labour markets so that labour force, labour supply, employment, the number of households and population are all equal. Nationally, capital and emissions permits are in fixed supply but they are inter-regionally mobile so that the given national supplies are allocated across regions so as to equalise rental rates:

(8) $R_{KI} = R_{KC}$

(9) $R_{EI} = R_{EC}$

2.3 Governments

The central government derives revenue from emission-permit rental and the VAT which is shared with the regional governments. In addition to its VAT share, each regional government levies tax on output in its own region. Finally, there are lump-sum transfers from the central to the regional governments. Each government (central, coastal and interior) receives tax revenue in the form of output and costlessly transforms this output into a homogeneous government good at the rate of one unit of the government good per unit of revenue expressed in terms of the composite good. The central government provides this to households as a consumption good in both regions, in per capita amounts which are the same for all households within the region but may differ across regions. Each regional government provides some output to households as a consumption good (in equal per capita amounts) within its own region as well as providing some to firms as infrastructure. There are no assets in the model so that neither households, nor firms nor governments can lend or borrow. Governments therefore must balance their budgets.

The central government's budget constraint is:

(10) $L_I GC_I + L_C GC_C = \theta T_V(L_I J_I + L_C J_C) + P^{1-\lambda} R_{EI} E_I + P^{-\lambda} R_{EC} E_C - TR_I - TR_C$

where GC_i is the amount of the government consumption good provided per household in region i, θ is the central government's share of VAT revenue and TR_i is the transfer to region i. The regional governments' budget constraints have the form:

(11a) $L_I GRH_I + GRF_I = T_I P^{1-\lambda} Y_I + (1-\theta) T_V L_I J_I + TR_I$

(11b) $L_C GRH_C + GRF_C = T_C P^{-\lambda} Y_C + (1-\theta) T_V L_C J_C + TR_C,$

where GRH_i is the provision of the government good pre household by the regional government in region i

2.4 Definition and Closure

The relationship between GH_i and its components which is given by:

(12) $GH_i = GRH_i + GC_i, \quad i = I, C$

Goods markets clear in each region:

(13a) $Y_I = L_I C_{II} + L_C C_{IC} + T_C Y_C + T_V L_I P^{\lambda-1} J_I + R_{EI} E_I$

(13b) $Y_C = L_I C_{CI} + L_C C_{CC} + T_C Y_C + T_V L_C P^{\lambda} J_C + R_{EC} E_C.$

Firms distribute profits to households in their own region in equal per capita amounts:

(14a) $\Pi F_I = L_I \Pi H_I$,

(14b) $\Pi F_C = L_C \Pi H_C$

The trade between regions must balance:

(15) $L_C P C_{IC} = L_I C_{CI}$

There is a given national labour force (= population), L:

(16) $L_I + L_C = L$,

a given national capital, K:

(17) $K_I + K_C = K$,

and a given national emission permit, E:

(18) $E_I + E_C = E$.

To summarise, the model consists of the 34 equations, (1) to (18) in 47 variables: V_i, C_{ji}, GH_i, P, J_i, ΠH_i, R_{Kj}, K_j, R_{Ej}, E_j, D_j, Y_j, L_j, ΠF_j, T_V, T_j, W_j, TR_i, GRH_i, GRF_j, GC_i, θ, L, μ, K, and E, of which 15 are exogenous:

D_j, T_j, TR_i, one of (GRH_I, GRF_I), one of (GRH_C, GRF_C), one of (GC_I, GC_C), θ, T_V, L, K, E and μ so that there are 32 endogenous variables:

V_i, C_{ji}, GH_i, P, J_i, ΠH_i, Y_j, L_j, ΠF_j, R_{Kj}, K_j, R_{Ej}, E_j, W_j, one of (GRH_I, GRF_I), one of (GRH_C, GRF_C), and one of (GC_I, GC_C).

Two equations, however, are redundant since (3), (5), (14), (15) and the household budget constraint can be used to derive (13) so that the balance between number of equations and number of endogenous variables is restored.

2.5 Short-run and long-run versions of the model

We distinguish between short-run and long-run versions of the model based, as in Krugman (1991), to differences in closure assumptions. We define the short run as the length of time before inter-regional migration begins to respond to the changes in V_I and V_C. In terms of the model, this simply involves suspending equations (4) and (16) and making L_I and L_C exogenous in the short-run simulations. The long run is used to refer to the simulation results using the model as set out above.

We note that while the short-run/long-run distinction suggests that the model has dynamic properties, this is not so in our case. Dynamics could be introduced in various ways. Principally, we could introduce investment and allow it to augment the capital stock as well as allow all agents to borrow and lend and so introduce dynamics through the accumulation of stocks of financial assets. Moreover, we might allow for underlying population and productivity growth. This would allow for a greater range of government policies (such as bond-financed expenditure changes) as well as the effect of pollution controls on the rate of growth of capital and, potentially, the steady-state capital stock. Despite these attractions to the introduction of serious dynamics, we forbear since extensions along these lines would greatly complicate the analysis; we leave such extensions for further research.[13]

2.6 The linearised, numerical version of the model

The model as it stands is too complicated to solve analytically so that we linearise it in terms of proportional changes and calibrate the parameters using data for China's regions. The linearised version is given in Appendix 2. The data and calibration are discussed in Appendix 3.

3. Results

In this section we report the results of seven simulations which were chosen to throw light on the questions we posed in the Introduction. Since the results are bound to depend on the particular parameter and closure assumptions which underlie the simulations, we also

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[13] An interesting recent paper which analyses a number of possible paths of transition for China to a low-carbon economy is the one by Wang and Watson (2010).

briefly report the results of a number of further simulations at the end of the section in order to assess the sensitivity of our results to these choices.

The seven simulations to be reported in this section are grouped into four groups:

1. The base case: an economy-wide reduction in pollution permits under the assumption that governments balance their budgets by adjusting consumption expenditure, the national government adjusting GC_I and GC_C equi-proportionately.
2. Regional governments attempt to offset the adverse effects of the cut in E by cutting tax on output in its region. We include two simulations in this group:
   a) The base case plus a tax cut by the region which is hardest-hit by the reduction in emissions permits, the interior region, in which the government cuts the tax on output, T_I.
   b) The base case plus a tax cut by both regional governments, T_I and T_C.
3. Regional governments attempt to offset the adverse effects by boosting infrastructure expenditure. There are two simulations in this group
   a) Only the interior regions reacts to the national reduction in emissions permits.
   b) Both regions increase infrastructure expenditure.
4. The central government attempts to offset the effects of the permit reduction by transferring resources from its budget to the regional government budgets. We include two shocks in this group depending on which governments receive the transfer. In each case the regional government balances its budget by adjusting infrastructure expenditure.
   a) transfer to the interior region, and
   b) transfer to both regions.

3.1 The base case: An economy-wide reduction in pollution permits

We begin with the base case in which the stock of emissions permits is reduced: the proportional change in the stock is set at -1. The results are in the first two columns of figures in Table 1.[14]

Table 1 about here

The “immediate” effect of the reduction in emissions permits is to drive up their price, equi-proportionately in each region since they are freely inter-regionally traded. In the short run industry in the interior reacts more strongly to this rise in the rental rate and reduces its use of pollution permits by more than the coast and in this sense the interior is harder-hit. This was contrary to our expectations which were that the pollution is largely a by-product of manufacturing which is heavily concentrated in the coastal region so that the coast would be harder-hit. However, the fact is that the industry in the interior is more pollution-intensive than that in the coast and this is reflected in our data base.[15] The greater reduction in pollution in the interior has flow-through effects on output with the decline in output in the interior exceeding that in the coast. This is reinforced by the movement of capital from the interior to the coast, reflecting a fall in the relative marginal product of capital in the interior. The output effects are quite small, however – a 10% reduction in pollution levels, say, reduces output by only 0.5% in the interior and by 0.3% in the coast. This is consistent with international evidence; see, e.g., Zhang (2000) and evidence cited there.

The reduction in permits also results in a fall in the marginal product of labour in each region so that demand for labour is reduced and, given flexible wages and a fixed labour

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[14] In order to save space, we report the simulation results only for main variables in Table 1. For the full simulation results, see Appendix 4.

[15] To see this note that the linearised marginal-productivity condition for pollution permits for industry j has the form $y_i - \sigma_{tj} t_j = r_{Ej} + e_j$. Moreover, the linearised production function is $y_j = \alpha_{Ej} e_j$ (for given supplies of other factors) so that we can write the marginal-productivity condition as $(\alpha_{Ej} - 1)e_j = r_{Ej}$ which implies a factor demand function with slope of $1/(\alpha_{Ej}-1)$. Then, given that $\alpha_{EI} = 0.0505$ and $\alpha_{EC} = 0.0328$, it follows that the permit demand function is steeper (the slope is more negative) for *I* than for *C* so that, for a given price change (both regions face a single national price), the use of permits will decline more in industry *I* than in industry *C*; in this sense, the interior is “harder-hit” than the coast.

supply, this results in a fall in wages, being larger for the interior than the coast. Profits also fall by more in the interior. The fall in wages and profits feed through into income which falls in each region although in this case the relative magnitudes are reversed with the fall being greater in the coast than in the interior. This reversal reflects the influence of relative prices. Since output falls by more in the interior, the relative price changes in favour of the interior good. Recall that households receive wages and profits in the form of output of the region of residence but that income is measured in terms of the composite good, so that the change in income reflects, in a sense, both a quantity and a valuation effect: interior residents receive less income in terms of interior output (the quantity effect) but it is more highly valued when converted to the composite good. The overall income effect shows that the valuation effect more than offsets the quantity effect.

A similar effect operates for the government consumption good – the regional governments receive tax revenue in the form of regional output but the government consumption good is measured in terms of the composite commodity and, again, the valuation effect more than offsets the quantity effect so that the reduction in the provision of the government good forced by the regional government budget constraint in the interior is more than offset by the favourable price effect; the opposite is the case in the coast. Both of these effects flow through into the effect on welfare so that, while welfare falls in both regions as a result of the reduction in emissions permits, it falls by more in the coast.

Hence, in the short run, output in both regions falls with the reduction in the interior being larger than that in the coast. Welfare effects contrast with output effects: the combined effect of relative price changes and the regional government budget constraints reverse the relative magnitudes as far as welfare is concerned – the coastal residents are worse-off in the short run than their “harder-hit” interior counterparts.

In the long run labour is mobile between regions and moves in response to relative utility changes: in this case from the coast to the interior. This partially offsets the short-run relative output movement with a rise in the output in the interior and a fall in the coast, although both still fall relative to the initial equilibrium. Not surprisingly, the rise in the relative price is smaller in the long run so that there is a partial reversal of the income effects although the reduction in income in the coast is still larger than it is in the interior. Similarly, the gap in the change in utility is also narrowed, although the short-run change is not reversed – the coastal residents are still harder-hit in terms of welfare than their interior fellow-citizens. Thus, the ability of the population to migrate from one region to another softens the inter-regional differences but does not remove them altogether.

To sum up the base case: in the short run the reduction in pollution permits reduces output, wages, profits, income and welfare in both regions. The output effects are greater for the interior which is more heavily reliant on pollution permits than the coast. Relative price changes and the constraints imposed by regional government budget balance, however, mean that the welfare effects are the reverse of this – the coast suffers more than the interior. This, in turn, results in migration from the coast to the interior in the long run which ameliorates the relative magnitude of the short-run effects but does not reverse them.

3.2 The regional governments react by cutting taxes

Since the cut in emissions permits has adverse output effects, it is likely that the regional government will react to attempt to offset these effects. We first consider the case where the regional government reaction is to cut taxes on output, starting with the case where only the government of the hardest-hit region reacts. We therefore simulate the effects of a cut in emissions combined with a cut in the tax on interior output.[16] The results are reported in the second pair of columns in Table 1.

In the short-run the tax cut raises the after-tax marginal products and increases demand for all factors in the interior, increasing the use of emissions permits and capital which partially offsets the output reduction observed in the base case. The effect is that output in the interior now falls by less than in in the base case and in this sense the interior government's policy is successful. There is a cost to the coast, however, where output now falls by more than in the base case although the relative magnitudes of output changes are not affected. The relative price now moves in favour of the coastal good so that income in the interior falls by more while income in the coast actually rises. This, together with the reduction in government consumption in the interior forced by the need for budget balance, reduces welfare in the interior by more than in the base case so that from a welfare point of view the tax cut was counterproductive.

In the long run labour migrates from the interior to the coast in response to the welfare gap, raising output in the coast and lowering it in the interior. The upshot of this is that the interior now performs relatively worse than it would have in the absence of the tax cut. The same is true in welfare terms – while the relative price effect is partially reversed, the coast is still better-off and the interior is even worse-off than it would have been in the absence of the tax cut.

Thus, while there are short-term benefits to the interior region from the tax cut in terms of output, in the long run the interior government's reaction is counterproductive in terms of both output and welfare under the combined effects of relative price changes and the regional government budget constraints.

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[16] We saw in the base case simulation that which region is hardest-hit by the pollution reduction depends on whether we focus on output or welfare. We choose to define "hardest-hit" in terms of output since output is more readily observable than welfare and, besides, the performance of regional governments is largely judged by their contribution to national GDP growth.

Suppose now that the coastal government also cuts taxes.[17] The results are reported in the third pair of columns in Table 1. In the short run the coastal government's policy is successful in ameliorating the adverse output effect of the pollution reduction, no matter whether the comparison is to the base case or to the case where only the interior government reacts. As we found previously, the welfare effects are the reverse – the coastal residents are made worse-off relative to both previous cases. In the long run migration occurs from the coast to the interior, reducing the relative output effects and partially offsetting the relative welfare effects. The result is that in the long run the coastal region is in a worse position than it would have been had its government not cut taxes irrespective of whether the interior government reacted or not. Thus whether the coastal government's policy was successful or not depends on whether we measure its effect in terms of output or welfare and whether we take a short- or long-run view.

3.3 The interior governments react by increasing infrastructure expenditure

An alternative policy which a regional government might undertake to attempt to offset the expected adverse effects of the central government's reducing pollution permits is to boost infrastructure expenditure. Again, we consider two shocks, the first in which only the interior government reacts and the second in which both regional governments implement a similar policy. The results of the unilateral policy are reported in the fourth pair of columns in Table 1.

In the short run the effect is to more than offset the reduction in output caused by the reduction in pollution permits. This effect is reinforced by permits and capital flows to the

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[17] One might wonder why the coastal government would "retaliate" in response to a policy which is largely beneficial to its citizens. We imagine that it must make a decision before the outcome of the interior government's tax cut is known, especially its long-run consequences. Alternatively, one could imagine that it must act before the interior government has implemented its policy and so acts simply in the expectation that the central government's pollution-reduction policy will have adverse consequences for each of the regional economies.

interior as their marginal products rise. Wages rise with an increase in the demand for the fixed labour supply and interior profits also increase. From the point of view of output, wages and profits the policy is entirely successful for the interior government. Not surprisingly, this success comes at the cost of worse outcomes for these variables in the coastal region. However, the substantial reversal of relative output changes (compared to the base case) has significant relative price effects and these, together with the reduction in the provision of consumption goods by the interior government driven by the budget constraint, result in welfare falling in the interior more than it did in the bases case and rising in the coast. The policy is therefore not successful in the welfare dimension.

The short-run welfare effects drive migration in the long run in which there is a substantial move of workers from the interior to the coast. This is accompanied by flows of capital and permits in the same direction (relative to the short-run equilibrium) and the combination of these flows reduces the output expansion in the interior and the output fall in the coast so that in the long run output rises in the interior and, while it still falls in the coast, it does so by less than in the base case. Thus the interior government's policy response might be judged to have a very successful outcome. The consequence for utility is not so favourable – it falls by more in the interior than in the absence of the infrastructure boost and rises relative to the base case in the coast so that the interior suffers and the coast benefits as a result of the interior government's policy.

Overall, the interior government's policy of increasing infrastructure expenditure is successful in terms of output in both the short and long runs whereas in terms of welfare, however, the policy must be judged a failure.

We now briefly consider the case where both regional governments react to the pollution-reduction policy by increasing infrastructure expenditure. The results are reported in the fifth pair of columns of Table 1.

In contrast to the previous case where only the interior government reacted, output, wages and profits now increase in both regions although, not surprisingly, the beneficial effects for the interior are tempered. In this dimension, both regions benefit relative to doing nothing although the interior's benefit would have been greater if the coast had not reacted. Given the different relative output effects, the relative price change is smaller although prices still move in favour of the coast so that incomes in both regions now rise in the short run. The effect on utility is tempered, however, by the fall in each regional government's provision of the consumption good required to maintain budge balance. In the case of the interior region this is large enough to more than offset the favourable effects of a higher income so that utility falls while for the coast the offset is less than complete. It is ironic that, while the interior region is better-off relative to the case where its government is the only one which reacts to the pollution reduction, it is worse-off relative to the base case where it did nothing. It would have been better for it to "leave well-enough alone" than to provoke retaliation by the coastal government. Similarly, while the coastal residents are better-off relative to the base case, they are worse-off than they would have been had their government simply let the interior government react unilaterally.

In the long run many of these effects are partially reversed due to labour migrating from the interior to the coast in response to short-run utility differentials. Was it worth the coastal government's while to follow the interior government's example and increase infrastructure expenditure? In terms of output it was: in both the short and long runs coastal output was higher than it would have been had only the interior government reacted. Indeed, it was also higher than it would have been had neither government reacted. In terms of welfare, however, it is a different story: the coastal residents would have been better-off if their government had simply let the interior government act alone.

3.4 The central government transfers budgetary resources to the regional governments

We now consider our final simulations in which we analyse the effects of a central government transfer of resources to the regions. We assume that the central government finances this by a reduction in its provision of government consumption goods in equal proportion in both regions and that the regional governments spend the extra resources on infrastructure.[18]

First, we assume again that the transfer is to the interior government only. The results are reported in the sixth pair of columns of Table 1. In this case there is effectively a transfer from government consumption expenditure in both regions to infrastructure expenditure in the interior region. The extra infrastructure in the interior boosts productive capacity in that region by enough to more than offset the adverse effects for output of the cut in pollution permits. Capital and emissions permits also flow from the coast to the interior relative to the base case and wages and profits rise in the interior. Interestingly, output, profits and wages in the coast continue to fall but by less than in the base case even though the transfer policy redistributes output from the coast to the interior; this happens because the relative price moves in favour of coastal output so that the coastal government can maintain its constant per capita level of consumption goods with fewer resources, the extra resources being used for infrastructure expenditure. Thus both regions benefits in terms of output, wages and, profits relative to the base case. However, income falls in the interior by more than it did in the base case and income rises in the coast, both under the effect of relative price changes. These flow through into welfare although they are tempered in the case of the coast and reinforced for the interior by the reduction in the central government's provision of the consumption good necessitated by the need to balance its budget in the face of increased transfers. In the short

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[18] Specifically, we assume that the endogenous variable for the central government is *GC* and for the regional governments it is *GRF*. An alternative for the latter is *GRH* but this is relatively uninteresting since it essentially redistributes some government consumption good from one region to the other. The case where the transfer is spent on consumption goods by the regional government is included in the sensitivity analysis which we discuss briefly at the end of this section.

run, therefore, the central government's transfer to the interior government benefits output in both regions but actually makes the interior residents worse-off than they would have been in the absence of the transfer.

In the long run workers move from the interior to the coast, thus partially offsetting the larger short-run effects in interior. Magnitudes of effects change but the relative magnitudes do not so that the short-run conclusions carry over to the long run.

Even though the coastal region benefits from a transfer to the interior region in both output and welfare dimensions, it is likely that the coastal government, too, will demand resources from the centre to help offset the expected adverse effects of the reduction in pollution permits. In the final simulation we briefly examine the effects of the central government's providing transfers to both regional governments, each of which spends the transferred resources on infrastructure. The results for this simulation are in the final two columns of Table 1.

The increase in infrastructure expenditure raises output in both regions but by more in the interior than in the coast. This reflects the fact that transfers are a relatively more important source of revenue for the interior than for the coast so that an equi-proportional increase results in a greater effect for the interior. Consequently, the subsequent effects are similar to the previous case – the relative magnitudes are the same but the absolute magnitudes are smaller. Thus, in the final analysis, output increases in both regions while utility increases in the coast but falls in the interior. Moreover the welfare loss in the interior is greater than it would have been had there been no offsetting transfer to the regions. In the long run, labour moves to the coast, the results of which are as in the previous simulation but, again, the magnitudes are smaller. The overall effects are similar to those in the short run – output rises in both regions but only the coast is made better-off relative to the base case, the interior being left worse-off than it would have been had there been no transfers.

3.5 Sensitivity Analysis

A well-known disadvantage of numerical simulations as a way of deriving model implications is that the results inevitably depend on the particular parameters as well as a range of modelling assumption such as closure. This is also true of the results we report in this paper and we ran a large number of extra simulations to assess the sensitivity of our results to these assumptions. In particular, we ran the following additional simulations, the results of which we report in Appendix 5:

1. Pollution reduction plus tax cuts with the regional government budget balanced by changes in infrastructure expenditure; both when only the interior responds and when both regional governments respond.
2. Pollution reduction plus transfer with the assumption that the endogenous variable for regional government is *GRH*.
3. Pollution reduction plus a boost of productivity by shocking total factor productivity.
4. The main simulations were carried out with a value for the substitution elasticity parameter in the utility function of 0.44 based on Mansur and Whalley (1984) which was the average of the range reported of 0.2 to 0.68. To assess the sensitivity of the results to this assumption, we repeated all the simulations reported in section 3 with a substitution elasticity in the utility function of 0.20.
5. We also repeated all the simulations reported in section 3 with a substitution elasticity in the utility function of 0.68.
6. We repeated all the simulations reported in section 3 using an alternative definition of the regions based on pollution intensity rather than geographic proximity.
7. We repeated all the simulations of section 3 under the assumption that the government allocates pollution permit reductions according to the proportions in the Twelfth Five-

Year Plan (-1.31 to the coast and -0.67 for the interior) rather than assuming them to be market allocated.

8. We repeated the tax-cut and transfer simulations under the assumption that the regional governments behave strategically by choosing *GRF* to maximise expenditure in the region.
9. We repeated the tax-cut and transfer simulations under the assumption that the regional government choose *GRH* to maximise welfare in the region.

The results of these extra simulations broadly support the conclusions we have reached above although, of course, the details change from one simulation to another

4. Conclusions

This paper has set out to analyse the regional economic effects of a national reduction in carbon emissions permits and assess the efficacy of policies which might be carried out by either the regional governments or the central government in an attempt to offset the adverse consequences of the pollution reduction on the regional economy. We did this within a simple two-region model designed to capture some salient features of the Chinese economy and used numerical simulations based on calibration using Chinese data.

Broadly, the simulation results show that the economic effects of a reduction in emissions were adverse and regionally differentiated but small. We found that the interior region was hardest-hit in terms of output, profits and wages but that income and welfare fell by less in the interior due to the combined effects of changes in the relative price and regional budget constraints.

Secondly, we examined the effectiveness of a range of policies which the regional or central governments might implement to offset the adverse effects of the pollution reduction.

We showed that, while in some cases such policies were effective, in many instances they were not or even counter-productive. Moreover, their effectiveness often depended on whether the policy was carried out in only one region or in both. Thus, for example, a cut in tax by the interior government improved the output position of the interior region. If, however, the coastal government “followed suit” and cut taxes too, then output benefit was reversed: in the short run output in the interior was lower than it would have been if both regional governments had “left well-enough alone”.

Finally, whether offsetting policies are successful or not depends importantly on whether success is measured in terms of output or welfare since these often moved in opposite directions under the combined effects of relative price changes and adjustments necessitated by the regional governments’ budget constraints. Thus, in the tax-cut example in the previous paragraph, unilateral action by the interior government raised output but reduced welfare relative to the no-policy-response position in the short run. In the long run the output advantage disappeared due to factor migration although the welfare effect was still worse for the interior. In general, the design of an appropriate policy will need to consider the objective of policy (output or welfare?), the time horizon (short run or long long?) and the likelihood of the other region’s government reacting.

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Table 1 Effects of a Reduction in Carbon Emission and Offsetting Policies

Variable	Base Case		Base Case + Tax Cut				Base Case + Infrastructure Increase				Base Case + Transfer			
	e = -1		e = -1 and t_I =-1		e = -1, t_I =-1, t_C =-1,		e = -1, grf_I=1		e=-1, grf_I=1, grf_C=1		e = -1, tr_I=1		e=-1, tr_I=1, tr_C=1	
	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR
v_I	-0.0142	-0.0354	-0.1387	-0.0723	0.0497	-0.0163	-0.2966	-0.1166	-0.1063	-0.0569	-0.1502	-0.0822	-0.1024	-0.0612
v_C	-0.0697	-0.0500	0.0352	-0.0264	-0.1229	-0.0618	0.1745	0.0078	0.0230	-0.0227	0.0693	0.0015	0.0308	-0.0104
j_I	-0.0050	-0.0308	-0.0963	-0.0155	0.1262	0.0460	-0.2176	0.0013	0.0068	0.0669	-0.1652	-0.0677	-0.0701	-0.0110
j_C	-0.0632	-0.0432	0.0369	-0.0258	-0.0241	0.0382	0.1701	0.0001	0.1077	0.0610	0.1640	0.0820	0.1534	0.1037
y_I	-0.0543	-0.0500	-0.0420	-0.0554	-0.0592	-0.0459	0.1105	0.0741	0.0921	0.0822	0.1134	0.1087	0.1190	0.1162
y_C	-0.0305	-0.0347	-0.0379	-0.0249	-0.0275	-0.0405	-0.0478	-0.0124	0.0510	0.0607	-0.0210	-0.0110	0.0278	0.0339
r_{EI}	0.9580	0.9579	0.9884	0.9886	1.0157	1.0154	1.0287	1.0294	1.0709	1.0711	1.0440	1.0469	1.0719	1.0737
r_{EC}	0.9580	0.9579	0.9884	0.9886	1.0157	1.0154	1.0287	1.0294	1.0709	1.0711	1.0440	1.0469	1.0719	1.0737
e_I	-1.0123	-1.0079	-0.9719	-0.9856	-1.0164	-1.0028	-0.9183	-0.9553	-0.9787	-0.9889	-0.9306	-0.9382	-0.9529	-0.9575
e_C	-0.9885	-0.9926	-1.0263	-1.0135	-0.9847	-0.9974	-1.0765	-1.0418	-1.0199	-1.0104	-1.0649	-1.0579	-1.0441	-1.0398
w_I	-0.0543	-0.0563	0.0165	0.0230	-0.0007	-0.0072	0.1105	0.1282	0.0921	0.0970	0.1134	0.1451	0.1190	0.1383
w_C	-0.0305	-0.0264	-0.0379	-0.0508	0.0593	0.0720	-0.0478	-0.0827	0.0510	0.0414	-0.0210	-0.0583	0.0278	0.0052
l_I	0.0000	0.0064	0.0000	-0.0200	0.0000	0.0198	0.0000	-0.0541	0.0000	-0.0149	0.0000	-0.0364	0.0000	-0.0221
l_C	0.0000	-0.0083	0.0000	0.0259	0.0000	-0.0258	0.0000	0.0703	0.0000	0.0193	0.0000	0.0473	0.0000	0.0287
p	0.1008	0.0469	-0.2308	-0.0617	0.2602	0.0924	-0.6716	-0.2134	-0.1746	-0.0489	-0.5701	-0.4044	-0.3872	-0.2867
grh_I	0.0017	-0.0241	-0.5156	-0.4346	-0.3117	-0.3922	-1.1485	-0.9290	-0.9429	-0.8826	0.0000	0.0000	0.0000	0.0000
grf_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0488	1.1556	1.1399	1.2047
grh_C	-0.0948	-0.0659	0.0628	-0.0276	-1.0428	-0.9530	0.2723	0.0272	-0.7643	-0.8316	0.0000	0.0000	0.0000	0.0000
grf_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000	0.2800	0.1586	0.7897	0.7161
gh_I	-0.0256	-0.0420	-0.3380	-0.2868	-0.1668	-0.2177	-0.7190	-0.5802	-0.5445	-0.5064	-0.2175	-0.2193	-0.2987	-0.2998
gh_C	-0.0820	-0.0690	0.0062	-0.0345	-0.4386	-0.3981	0.1236	0.0133	-0.2863	-0.3166	-0.3137	-0.3163	-0.4308	-0.4323

Notes: The symbols in the first column and at the head of the columns of results are the proportional changes of their upper-case counterparts; thus, for example, v_I is the proportional change in V_I. SR and LR are abbreviations of “short run” and “long run”.

Appendix 1: Definition of variables

V_i = utility of the representative household, region i
C_{Ii}= real private consumption of interior output per household, region i
C_{Ci}= real private consumption of coastal output per household, region i
GH_i = real government-provided consumption per household, region i.
P = price of interior output in terms of coastal output
J_i= real household income (net of VAT), region i
W_j= real wage income, industry j
ΠH_i = real profit distribution per household, region i
R_{Kj}= capital rental rate, industry j
K_j= capital stock, industry j
K = national capital stock
R_{Ej}= emission permit rental rate, industry j
E_j= emission permit, industry j
E = national emission permit
D_j= productivity parameter, industry j
Y_j = real output, industry j
L_j= employment, industry j
L= national population
ΠF_j = firm profit, industry j
T_v = value added tax rate
T_j = output tax rate, industry j
TR_i = lump-sum transfer from the central government to regional government i
GRH_i= real regional government-provided consumption good per household, region i
GRF_j= real regional government-provided public good, industry j
GC_i= real central government-provided consumption good per household in region i
θ= share of valued tax to the central government
μ = *hukou* parameter

Appendix 2: Linearised version of the model

The model of section 2 is linearised in terms of proportional differences by taking logarithms and differentials of each equation. The linearised form of equations (1) to (18) (excluding equations (13) which are redundant) of the model are as follows, with the linearised form having the same number as the original equation but being distinguished by a prime.
The linearised utility function is:

(1') $v_i = \sigma_{caiv} c_{Ii} + \sigma_{cmiv} c_{Ci} + \sigma_{ghiv} gh_i$, *i=I, C*

where lower-case letters represent the proportional changes (log differential) of their upper-case counterparts and

$$\sigma_{caiv} = \frac{\gamma_{Ii} C_{Ii}^{-\rho}}{\gamma_{Ii} C_{Ii}^{-\rho} + \gamma_{Ci} C_{Ci}^{-\rho} + \delta_i GH_i^{-\rho}},$$

$$\sigma_{cmiv} = \frac{\gamma_{Ci} C_{Ci}^{-\rho}}{\gamma_{Ii} C_{Ii}^{-\rho} + \gamma_{Ci} C_{Ci}^{-\rho} + \delta_i GH_i^{-\rho}},$$

$$\sigma_{ghiv} = \frac{\delta_i GH_i^{-\rho}}{\gamma_{Ii} C_{Ii}^{-\rho} + \gamma_{Ci} C_{Ci}^{-\rho} + \delta_i GH_i^{-\rho}}.$$

The linearised consumption demand functions are:

(2a') $c_{Ii} = j_i + \lambda p - \sigma_{cai} p - \sigma_{elas} p$, *i=I, C*

where $\sigma_{cai} = \dfrac{\frac{\rho}{\rho+1}}{1 + P^{\frac{-\rho}{\rho+1}} (\frac{\gamma_{Ci}}{\gamma_{Ii}})^{\frac{1}{\rho+1}}}$, $\sigma_{elas} = \dfrac{1}{\rho+1}$, and

(2b') $c_{Ci} = j_i + \lambda p - \sigma_{cai} p$ *i=I, C.*

The linearised definitions of real household income are:

(3a') $\sigma_{tv} t_v + j_I = \sigma_{j\pi h1}[(1-\lambda)p + \sigma_{j\pi h\pi h1} \pi h_1 + \sigma_{j\pi hwA} w_I + \sigma_{j\pi hkA}(r_{KI} + k_I - l)]$
$+ \sigma_{jrkM}(-\lambda p + r_{KC} + k_C - l)$

where $\sigma_{tv} = \dfrac{T_v}{1+T_v}$, $\sigma_{j\pi hI} = \dfrac{P^{1\text{-}\lambda}[\Pi H_1 + W_I + R_{KI} K_I / L]}{(1+T_V) J_1}$, $\sigma_{jrkM} = \dfrac{P^{-\lambda} R_{KC} K_C / L}{(1+T_V) J_1}$

$$\sigma_{j\pi h\pi h1} = \frac{\Pi H_1}{\Pi H_1 + W_I + R_{KI} K_I / L}, \sigma_{j\pi hwA} = \frac{W_I}{\Pi H_1 + W_I + R_{KI} K_I / L}, \sigma_{j\pi hkA} = \frac{R_{KI} K_I / L}{\Pi H_1 + W_I + R_{KI} K_I / L}$$

(3b') $\sigma_{tv} t_v + j_C = \sigma_{j\pi hC}[-\lambda p + \sigma_{j\pi h\pi hC} \pi h_C + \sigma_{j\pi hwM} w_C + \sigma_{j\pi hkM}(r_{KC} + k_C - l)]$
$+ \sigma_{jrkA}[(1-\lambda)p + r_{KI} + k_I - l]$

where $\sigma_{j\pi hC} = \dfrac{P^{\text{-}\lambda}[\Pi H_C + W_C + R_{KC} K_C / L]}{(1+T_V) J_C}$, $\sigma_{jrkA} = \dfrac{P^{1-\lambda} R_{KI} K_I / L}{(1+T_V) J_C}$

$$\sigma_{j\pi h\pi hC} = \frac{\Pi H_C}{\Pi H_C + W_C + R_{KC} K_C / L}, \sigma_{j\pi hwM} = \frac{W_C}{\Pi H_C + W_C + R_{KC} K_C / L}$$

$$\sigma_{j\pi hkM} = \frac{R_{KC} K_C / L}{\Pi H_C + W_C + R_{KC} K_C / L}$$

The linearised migration equilibrium condition corresponding to equation (4) is:

(4') $v_C = v_I + \mu * \mu \log(\dfrac{L_C / A_C}{L_I / A_I}) + \mu(l_C - l_I)$

where $\mu^* = d\mu/\mu$ and we have used the obvious assumption that area is constant.
The linearised production functions are:

(5’) $y_j = d_j + \alpha_{Lj} l_j + \alpha_{Ej} e_j + \alpha_{Kj} k_j + \alpha_{Gj} grf_j$, $j=I, C$.

The linearised profit definitions are given by:

(6’) $\pi f_j = \sigma_{y\pi fj} y_j - \sigma_{tj} \sigma_{y\pi fj} t_j - \sigma_{w\pi fj}(w_j + l_j)$

$-\sigma_{k\pi fj}(k_j + r_{kj}) - \sigma_{e\pi fj}(e_j + r_{ej})$, $j=I, C$

where $\sigma_{y\pi fj} = \frac{(1-T_j)Y_j}{\Pi F_j}$, $\sigma_{tj} = \frac{T_j}{1-T_j}$, $\sigma_{w\pi f j} = \frac{W_j L_j}{\Pi F_j}$, $\sigma_{k\pi f j} = \frac{R_{Kj} K_j}{\Pi F_j}$, $\sigma_{e\pi f j} = \frac{R_{ej} E_j}{\Pi F_j}$

The manufacturing industry’s profit-maximisation condition in linear form is:

(7a’) $y_i - \sigma_{tj} t_j = w_j + l_j$, $j=I, C$

(7b’) $y_i - \sigma_{tj} t_j = r_{Kj} + k_j$, $j=I, C$

(7c’) $y_i - \sigma_{tj} t_j = r_{Ej} + e_j$, $j=I, C$

The capital allocation equilibrium condition is:

(8’) $r_{KI} = r_{KC}$.

The emission permits allocation equilibrium condition is:

(9’) $r_{EI} = r_{EC}$.

The central government’s budget constraint is linearised as:

(10’) $\sigma_{gcIgc}(l_I + gc_I) + \sigma_{gcCgc}(l_C + gc_C) + \sigma_{gctrI} tr_I + \sigma_{gctrC} tr_C - \sigma_{gcreA}((1-\lambda)p + r_{EI} + e_I)$

$-\sigma_{gcreM}(-\lambda p + r_{EC} + e_C) = \theta^* + t_v + \sigma_{jIj}(l_I + j_I) + \sigma_{jCj}(l_C + j_C)$

where $\sigma_{gcIgc} = \frac{L_I GC_I}{L_I GC_I + L_C GC_C + TR_I + TR_C - P^{1-\lambda} R_{EI} E_I - P^{-\lambda} R_{EC} E_C}$,

$$\sigma_{gcCgc} = \frac{L_C GC_C}{L_I GC_I + L_C GC_C + TR_I + TR_C - P^{1-\lambda} R_{EI} E_I - P^{-\lambda} R_{EC} E_C}$$

$$\sigma_{gctrI} = \frac{TR_I}{L_I GC_I + L_C GC_C + TR_I + TR_C - P^{1-\lambda} R_{EI} E_I - P^{-\lambda} R_{EC} E_C}$$

$$\sigma_{gctrC} = \frac{TR_C}{L_I GC_I + L_C GC_C + TR_I + TR_C - P^{1-\lambda} R_{EI} E_I - P^{-\lambda} R_{EC} E_C}$$

$$\sigma_{gcreA} = \frac{P^{1-\lambda} R_{EI} E_I}{L_I GC_I + L_C GC_C + TR_I + TR_C - P^{1-\lambda} R_{EI} E_I - P^{-\lambda} R_{EC} E_C}$$

$$\sigma_{gcreM} = \frac{P^{-\lambda} R_{EC} E_C}{L_I GC_I + L_C GC_C + TR_I + TR_C - P^{1-\lambda} R_{EI} E_I - P^{-\lambda} R_{EC} E_C}$$

$\sigma_{jIj} = \frac{L_I J_I}{L_I J_I + L_C J_C}$, $\sigma_{jCj} = \frac{L_C J_C}{L_I J_I + L_C J_C}$, $\theta^* = d\theta/\theta$,

The regional governments’ budget constraints are linearised as:

(11a’) $\sigma_{grhIgr}(l_I + grh_I) + \sigma_{grfAgr} grf_I - \sigma_{grtrI} tr_I$

$= \sigma_{tAgr}(t_I + p - \lambda p + y_I) + \sigma_{tvIgr}(-\sigma_\theta \theta^* + t_V + l_I + j_I)$

where $\sigma_{grhIgr} = \frac{L_I GRH_I}{L_I GRH_I + GRF_I - TR_I}$, $\sigma_{grfAgr} = \frac{GRF_I}{L_I GRH_I + GRF_I - TR_I}$,

$\sigma_{grtrI} = \frac{TR_I}{L_I GRH_I + GRF_I - TR_I}$, $\sigma_\theta = \frac{\theta}{1-\theta}$,

$\sigma_{tAgr} = \frac{T_I P^{1-\lambda} Y_I}{T_I P^{1-\lambda} Y_I + (1-\theta) T_V L_I J_I}$, $\sigma_{tvIgr} = \frac{(1-\theta) T_V N_I J_I}{T_I P^{1-\lambda} Y_I + (1-\theta) T_V L_I J_I}$, and

(11b’) $\sigma_{grhCgr}(l_C + grh_C) + \sigma_{grfMgr} grf_C - \sigma_{grtrC} tr_C$

$= \sigma_{tMgr}(t_C - \lambda p + y_C) + \sigma_{tvCgr}(-\sigma_\theta \theta^* + t_V + l_C + j_C)$

where $\sigma_{grhCgr} = \frac{L_C GRH_C}{L_C GRH_C + GRF_C - TR_C}$, $\sigma_{grfMgr} = \frac{GRF_C}{L_C GRH_C + GRF_C - TR_C}$,

$\sigma_{grtrC} = \frac{TR_C}{L_C GRH_C + GRF_C - TR_C}$

$\sigma_{tMgr} = \frac{T_C P^{-\lambda} Y_C}{T_C P^{-\lambda} Y_C + (1-\theta) T_V L_C J_C}$, $\sigma_{tvCgr} = \frac{(1-\theta) T_V L_C J_C}{T_C P^{-\lambda} Y_C + (1-\theta) T_V L_C J_C}$.

The definition of GH_i is linearised as:

(12’) $gh_i = \sigma_{grhigh} grh_i + \sigma_{gcigh} gc_i$, $i=I, C$

where $\sigma_{grhigh} = \frac{GRH_i}{GH_i}$, $\sigma_{gcigh} = \frac{GC_i}{GH_i}$.

Equations (13), the goods markets clearing conditions, are dropped from the model due to the redundancy result explained in section 2.

The profit distribution conditions can be linearised to give:

(14a’) $\pi f_I = l_I + \pi h_I$,

(14b’) $\pi f_C = l_C + \pi h_C$.

The balance of trade condition in linear form is:

(15’) $l_C + p + c_{IC} = l_I + c_{CI}$.

The national employment constraint results in the following linearisedcondition:

(16’) $\sigma_{lI} l_I + \sigma_{lC} l_C = l$

where $\sigma_{lI} = L_I / L, \sigma_{lC} = L_C / L$.

The national capital constraint results in the following linearised condition:

(17’) $\sigma_{kA} k_I + \sigma_{kM} k_C = k$

where $\sigma_{kA} = K_I / K, \sigma_{kM} = K_C / K$.

The national emission permits constraint results in the following linearised condition:

(18’) $\sigma_{eA} e_I + \sigma_{eM} e_C = e$

where $\sigma_{eA} = E_I / E, \sigma_{eM} = E_C / E$.

Appendix 3: Calibrating the linearised model

The linearised model contains a number of parameters which have to be evaluated before the model can be put to work to simulate the effects of various shocks. These parameters fall into two groups. The first are parameters which appear in model relationships; γ_{ji}, δ_i and ρ appear in the utility function (1) and α_{Gj}, α_{Ej}, α_{Kj}, and α_{Lj} appear in the production function (5). The remainder, on the other hand, are linearisation parameters which are all shares of some sort. The model parameters were evaluated as follows. For the parameters of the utility function we broadly followed the method set out in Mansur and Whalley (1984) in which the substitution elasticity $\sigma = 1/(1+\rho)$ is derived from the equation:

$$\sigma = \frac{\eta_i - \gamma_i^{\sigma}}{1-\gamma_i^{\sigma}}$$

where η_i is the (uncompensated) own-price elasticity, values for which were derived as averages from Table 4 in Mansur and Whalley, and γ_i^{σ} can be derived from ratios of consumption expenditure and our assumption that $\gamma_{Ii} + \gamma_{Ci} + \delta_i = 1$.

The production parameters, α_{Gj}, α_{Ej}, α_{Kj}, and α_{Lj}. were calibrated as follows. Using the firm's first-order condition for profit-maximisation, equation (7a)-(7c), and the assumption that the firm can choose the government expenditure to maximize profit, we can write:

$$\alpha_{Lj} = \frac{W_j L_j}{Y_j(1-T_j)},$$

$$\alpha_{Kj} = \frac{R_{Kj} K_j}{Y_j(1-T_j)}$$

$$\alpha_{Ej} = \frac{R_{Ej} E_j}{Y_j(1-T_j)}, \quad \text{and}$$

$$\alpha_{Gj} = \frac{GRF_j}{Y_j(1-T_j)}$$

and use data for the wage bill, capital rental income, permit rental income, government infrastructure expenditure and output net of tax to compute the parameters.

The linearisation parameters can be evaluated directly from their definitions, given values for C_{ji}, P, θ, μ, ΠH_i, R_{Kj}, K_j, R_{Ej}, E_j, W_j, T_v, T_j, Y_j, ΠF_j, L_j, GC_i, J_i, GRH_i, GRF_i, GH_i and TR_i. We normalise P at unity and also set the immigration parameter, μ, at unity; θ is set at 0.75 to reflect the current division of VAT revenue between the central and regional governments. We then use these assumed values and the data for C_{ji}, GRH_i, GRF_j, $R_{Kj}K_j$, $R_{Ej}E_j$, GC_i, L_j, W_j, TR_i to gether with the model definitions to calculate the value of all other variables. The use of the model definitions ensures that the parameter values used in the simulations are consistent with the model constraints.

We therefore need data for two regions, the interior and the coast, for the variables C_{ji}, GRH_i, GRF_j, $R_{Kj}K_j$, $R_{Ej}E_j$, GC_i, L_j, W_j, TR_i. The data we use are based on those for the Chinese provinces which we have allocated to the two regions as follows. The coastal region consists of Beijing, Tianjin, Hebei, Guangdong, Hainan, Shandong, Fujian, Zhejiang, Jiangsu, Shanghai, Liaoning and Guangxi with the remaining provinces being allocated to the interior region. The interior therefore consist of: Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Sichuan, Chongqing, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Tibet, Xinjiang. For each region we use data averaged over the 11-year period 2000-2010 to avoid cyclical influences on the share parameters. The data for emission permit rental income were generated as follows. We first computed the CO_2 emission in each province using the energy consumption data for coal, gas and oil and their emission factor index and then use the world market CO_2 trading price to compute the rental income. The energy consumption data come from *Comprehensive Statistical Data and Materials on 60 Years of New China (SSB, 2010)* and *China Energy Statistical Year Book* (SSB, various issues), the emission factor indexes for coal, gas and oil come from IPCC (2006), and the CO_2 trading price data come from *State and Trends of the Carbon Market* (World Bank, various issues).All the other data come from *China Statistics Year Book* (SSB, various issues) except for data on area used to compute population density for the migration equilibrium condition, equation (4’), which come from *China Civil Affairs Statistical Yearbook 2005* (SSB, 2005).

Appendix4: Full Simulation Results in Table 1

Variable	Base Case		Base Case+ Tax Cut in Interior		Base Case +Tax Cut in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0142	-0.0354	-0.1387	-0.0723	0.0497	-0.0163
v_C	-0.0697	-0.0500	0.0352	-0.0264	-0.1229	-0.0618
c_{II}	-0.0363	-0.0453	-0.0248	0.0036	0.0455	0.0174
c_{CI}	0.0081	-0.0247	-0.1263	-0.0235	0.1600	0.0580
c_{IC}	-0.0927	-0.0569	0.1045	-0.0077	-0.1002	0.0112
c_{CC}	-0.0483	-0.0363	0.0029	-0.0349	0.0143	0.0519
gh_I	-0.0256	-0.0420	-0.3380	-0.2868	-0.1668	-0.2177
gh_C	-0.0820	-0.0690	0.0062	-0.0345	-0.4386	-0.3981
j_I	-0.0050	-0.0308	-0.0963	-0.0155	0.1262	0.0460
j_C	-0.0632	-0.0432	0.0369	-0.0258	-0.0241	0.0382
πh_I	-0.0543	-0.0563	0.0165	0.0230	-0.0007	-0.0072
πh_C	-0.0305	-0.0264	-0.0379	-0.0508	0.0619	0.0747
y_I	-0.0543	-0.0500	-0.0420	-0.0554	-0.0592	-0.0459
y_C	-0.0305	-0.0347	-0.0379	-0.0249	-0.0275	-0.0405
l_I	0.0000	0.0064	0.0000	-0.0200	0.0000	0.0198
l_C	0.0000	-0.0083	0.0000	0.0259	0.0000	-0.0258
r_{KI}	-0.0396	-0.0405	-0.0171	-0.0142	0.0363	0.0334
r_{KC}	-0.0396	-0.0405	-0.0171	-0.0142	0.0363	0.0334
k_I	-0.0147	-0.0094	0.0336	0.0172	-0.0370	-0.0208
k_C	0.0091	0.0059	-0.0208	-0.0107	0.0230	0.0129
r_{EI}	0.9580	0.9579	0.9884	0.9886	1.0157	1.0154
r_{EC}	0.9580	0.9579	0.9884	0.9886	1.0157	1.0154
e_I	-1.0123	-1.0079	-0.9719	-0.9856	-1.0164	-1.0028
e_C	-0.9885	-0.9926	-1.0263	-1.0135	-0.9847	-0.9974
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0500	0.0165	0.0030	-0.0007	0.0126
πf_C	-0.0305	-0.0347	-0.0379	-0.0249	0.0619	0.0489
w_I	-0.0543	-0.0563	0.0165	0.0230	-0.0007	-0.0072
w_C	-0.0305	-0.0264	-0.0379	-0.0508	0.0593	0.0720
p	0.1008	0.0469	-0.2308	-0.0617	0.2602	0.0924
grh_I	0.0017	-0.0241	-0.5156	-0.4346	-0.3117	-0.3922
grf_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
grh_C	-0.0948	-0.0659	0.0628	-0.0276	-1.0428	-0.9530
grf_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
gc_I	-0.0712	-0.0717	-0.0418	-0.0403	0.0748	0.0733
gc_C	-0.0712	-0.0717	-0.0418	-0.0403	0.0748	0.0733
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	-1.0000	-1.0000	-1.0000	-1.0000
t_C	0.0000	0.0000	0.0000	0.0000	-1.0000	-1.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix4: Full Simulation Results in Table 1 (continued)

Variable	Base Case		Base Case +Infrastructure Increase in Interior		Base Case +Infrastructure Increase in two Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0142	-0.0354	-0.2966	-0.1166	-0.1063	-0.0569
v_C	-0.0697	-0.0500	0.1745	0.0078	0.0230	-0.0227
c_{II}	-0.0363	-0.0453	-0.0095	0.0674	0.0610	0.0821
c_{CI}	0.0081	-0.0247	-0.3050	-0.0265	-0.0159	0.0605
c_{IC}	-0.0927	-0.0569	0.3666	0.0625	0.1587	0.0753
c_{CC}	-0.0483	-0.0363	0.0711	-0.0314	0.0819	0.0538
gh_I	-0.0256	-0.0420	-0.7190	-0.5802	-0.5445	-0.5064
gh_C	-0.0820	-0.0690	0.1236	0.0133	-0.2863	-0.3166
j_I	-0.0050	-0.0308	-0.2176	0.0013	0.0068	0.0669
j_C	-0.0632	-0.0432	0.1701	0.0001	0.1077	0.0610
πh_I	-0.0543	-0.0563	0.1105	0.1282	0.0921	0.0970
πh_C	-0.0305	-0.0264	-0.0478	-0.0827	0.0510	0.0414
y_I	-0.0543	-0.0500	0.1105	0.0741	0.0921	0.0822
y_C	-0.0305	-0.0347	-0.0478	-0.0124	0.0510	0.0607
l_I	0.0000	0.0064	0.0000	-0.0541	0.0000	-0.0149
l_C	0.0000	-0.0083	0.0000	0.0703	0.0000	0.0193
r_{KI}	-0.0396	-0.0405	0.0128	0.0207	0.0668	0.0689
r_{KC}	-0.0396	-0.0405	0.0128	0.0207	0.0668	0.0689
k_I	-0.0147	-0.0094	0.0977	0.0534	0.0254	0.0133
k_C	0.0091	0.0059	-0.0606	-0.0331	-0.0158	-0.0082
r_{EI}	0.9580	0.9579	1.0287	1.0294	1.0709	1.0711
r_{EC}	0.9580	0.9579	1.0287	1.0294	1.0709	1.0711
e_I	-1.0123	-1.0079	-0.9183	-0.9553	-0.9787	-0.9889
e_C	-0.9885	-0.9926	-1.0765	-1.0418	-1.0199	-1.0104
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0500	0.1105	0.0741	0.0921	0.0822
πf_C	-0.0305	-0.0347	-0.0478	-0.0124	0.0510	0.0607
w_I	-0.0543	-0.0563	0.1105	0.1282	0.0921	0.0970
w_C	-0.0305	-0.0264	-0.0478	-0.0827	0.0510	0.0414
p	0.1008	0.0469	-0.6716	-0.2134	-0.1746	-0.0489
grh_I	0.0017	-0.0241	-1.1485	-0.9290	-0.9429	-0.8826
grf_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
grh_C	-0.0948	-0.0659	0.2723	0.0272	-0.7643	-0.8316
grf_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
gc_I	-0.0712	-0.0717	-0.0027	0.0014	0.1198	0.1210
gc_C	-0.0712	-0.0717	-0.0027	0.0014	0.1198	0.1210
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix4: Full Simulation Results in Table 1 (continued)

Variable	Base Case		Base Case +Transfer to Infrastructure in Interior		Base Case +Transfer to Infrastructure Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0142	-0.0354	-0.1502	-0.0822	-0.1024	-0.0612
v_C	-0.0697	-0.0500	0.0693	0.0015	0.0308	-0.0104
c_{II}	-0.0363	-0.0453	0.0115	0.0576	0.0499	0.0778
c_{CI}	0.0081	-0.0247	-0.2393	-0.1203	-0.1205	-0.0483
c_{IC}	-0.0927	-0.0569	0.3308	0.2003	0.2667	0.1876
c_{CC}	-0.0483	-0.0363	0.0799	0.0224	0.0963	0.0614
gh_I	-0.0256	-0.0420	-0.2175	-0.2193	-0.2987	-0.2998
gh_C	-0.0820	-0.0690	-0.3137	-0.3163	-0.4308	-0.4323
j_I	-0.0050	-0.0308	-0.1652	-0.0677	-0.0701	-0.0110
j_C	-0.0632	-0.0432	0.1640	0.0820	0.1534	0.1037
πh_I	-0.0543	-0.0563	0.1134	0.1451	0.1190	0.1383
πh_C	-0.0305	-0.0264	-0.0210	-0.0583	0.0278	0.0052
y_I	-0.0543	-0.0500	0.1134	0.1087	0.1190	0.1162
y_C	-0.0305	-0.0347	-0.0210	-0.0110	0.0278	0.0339
l_I	0.0000	0.0064	0.0000	-0.0364	0.0000	-0.0221
l_C	0.0000	-0.0083	0.0000	0.0473	0.0000	0.0287
r_{KI}	-0.0396	-0.0405	0.0305	0.0349	0.0627	0.0654
r_{KC}	-0.0396	-0.0405	0.0305	0.0349	0.0627	0.0654
k_I	-0.0147	-0.0094	0.0829	0.0739	0.0563	0.0508
k_C	0.0091	0.0059	-0.0514	-0.0458	-0.0349	-0.0315
r_{EI}	0.9580	0.9579	1.0440	1.0469	1.0719	1.0737
r_{EC}	0.9580	0.9579	1.0440	1.0469	1.0719	1.0737
e_I	-1.0123	-1.0079	-0.9306	-0.9382	-0.9529	-0.9575
e_C	-0.9885	-0.9926	-1.0649	-1.0579	-1.0441	-1.0398
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0500	0.1134	0.1087	0.1190	0.1162
πf_C	-0.0305	-0.0347	-0.0210	-0.0110	0.0278	0.0339
w_I	-0.0543	-0.0563	0.1134	0.1451	0.1190	0.1383
w_C	-0.0305	-0.0264	-0.0210	-0.0583	0.0278	0.0052
p	0.1008	0.0469	-0.5701	-0.4044	-0.3872	-0.2867
grh_I	0.0017	-0.0241	0.0000	0.0000	0.0000	0.0000
grf_I	0.0000	0.0000	1.0488	1.1556	1.1399	1.2047
grh_C	-0.0948	-0.0659	0.0000	0.0000	0.0000	0.0000
grf_C	0.0000	0.0000	0.2800	0.1586	0.7897	0.7161
gc_I	-0.0712	-0.0717	-0.5801	-0.5849	-0.7967	-0.7996
gc_C	-0.0712	-0.0717	-0.5801	-0.5849	-0.7967	-0.7996
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
tr_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000

Appendix5: Full Simulation Test Results

To test the sensitivity of our results we ran the following additional simulations, the results of which we report below:

1. Pollution reduction plus tax cuts with the regional government budget balanced by changes in infrastructure expenditure; both when only the interior responds and when both regional governments respond.
2. Pollution reduction plus transfer with the assumption that the endogenous variable for regional government is grh.
3. Pollution reduction plus a boost of productivity by shocking tfp.
4. The main simulations were carried out with a value for the substitution elasticity parameter in the utility function of 0.44 based on Mansur and Whalley (1984) which was the average of the range reported of 0.2 to 0.68. To assess the sensitivity of the results to this assumption, we repeated all the simulations reported in section 3 with a substitution elasticity in the utility function of 0.20.
5. We also repeated all the simulations reported in section 3 with a substitution elasticity in the utility function of 0.68.
6. We repeated all the simulations reported in section 3 using an alternative definition of the regions based on pollution intensity rather than geographic proximity.
7. We repeated all the simulations of section 3 under the assumption that the government allocates pollution permits according to the proportions in the Twelfth Five-Year Plan (1.31 to the coast and 0.67 for the interior) rather than assuming them to be market allocated.
8. We repeated the tax-cut and transfer simulations under the assumption that the regional governments behave strategically by choosing *grf* to maximise expenditure in the region.
9. We repeated the tax-cut and transfer simulations under the assumption that the regional government choose *grh* to maximise welfare in the region.

Appendix5: Sensitivity Test 1, Full Simulation Results for A Cut in Tax (grf endogenous)

Variable	Base Case		Base Case+ Tax Cut in Interior		Base Case+Tax Cut in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0282	-0.0377	-0.0268	-0.0380	-0.0384	-0.0458
v_C	-0.0588	-0.0494	-0.0630	-0.0518	-0.0622	-0.0549
c_{II}	-0.0435	-0.0499	-0.0447	-0.0523	-0.0502	-0.0552
c_{CI}	-0.0150	-0.0316	-0.0104	-0.0301	-0.0294	-0.0423
c_{IC}	-0.0798	-0.0616	-0.0882	-0.0667	-0.0768	-0.0626
c_{CC}	-0.0513	-0.0433	-0.0540	-0.0445	-0.0559	-0.0496
gh_I	-0.0316	-0.0313	-0.0325	-0.0322	-0.0384	-0.0382
gh_C	-0.0455	-0.0452	-0.0468	-0.0464	-0.0553	-0.0551
j_I	-0.0234	-0.0370	-0.0205	-0.0366	-0.0355	-0.0461
j_C	-0.0608	-0.0494	-0.0655	-0.0519	-0.0629	-0.0540
πh_I	-0.0551	-0.0595	-0.0586	-0.0638	-0.0584	-0.0619
πh_C	-0.0398	-0.0346	-0.0402	-0.0341	-0.0460	-0.0419
y_I	-0.0551	-0.0544	-0.1170	-0.1163	-0.1169	-0.1164
y_C	-0.0398	-0.0412	-0.0402	-0.0419	-0.1354	-0.1365
l_I	0.0000	0.0051	0.0000	0.0060	0.0000	0.0040
l_C	0.0000	-0.0066	0.0000	-0.0078	0.0000	-0.0052
r_{KI}	-0.0457	-0.0463	-0.0472	-0.0480	-0.0524	-0.0529
r_{KC}	-0.0457	-0.0463	-0.0472	-0.0480	-0.0524	-0.0529
k_I	-0.0094	-0.0082	-0.0113	-0.0098	-0.0061	-0.0051
k_C	0.0058	0.0051	0.0070	0.0061	0.0038	0.0031
r_{EI}	0.9528	0.9524	0.9509	0.9504	0.9320	0.9317
r_{EC}	0.9528	0.9524	0.9509	0.9504	0.9320	0.9317
e_I	-1.0079	-1.0068	-1.0095	-1.0082	-0.9904	-0.9896
e_C	-0.9926	-0.9936	-0.9911	-0.9923	-1.0089	-1.0097
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0551	-0.0544	-0.0586	-0.0578	-0.0584	-0.0579
πf_C	-0.0398	-0.0412	-0.0402	-0.0419	-0.0460	-0.0471
w_I	-0.0551	-0.0595	-0.0586	-0.0638	-0.0584	-0.0619
w_C	-0.0398	-0.0346	-0.0402	-0.0341	-0.0486	-0.0446
p	0.0648	0.0417	0.0778	0.0505	0.0474	0.0294
grh_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
grf_I	-0.0159	-0.0308	-0.4670	-0.4846	-0.4814	-0.4930
grh_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
grf_C	-0.0970	-0.0801	-0.1048	-0.0848	-1.1764	-1.1632
gc_I	-0.0842	-0.0835	-0.0866	-0.0858	-0.1023	-0.1018
gc_C	-0.0842	-0.0835	-0.0866	-0.0858	-0.1023	-0.1018
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	-1.0000	-1.0000	-1.0000	-1.0000
t_C	0.0000	0.0000	0.0000	0.0000	-1.0000	-1.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 2, Full Simulation Results (transfer to consumption)

Variable	Base Case		Base Case +Transfer to Consumption in Interior		Base Case +Transfer to Consumption in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0142	-0.0354	0.0927	0.0021	0.0692	-0.0061
v_C	-0.0697	-0.0500	-0.1444	-0.0605	-0.1279	-0.0582
c_{II}	-0.0363	-0.0453	-0.0363	-0.0750	-0.0363	-0.0684
c_{CI}	0.0081	-0.0247	0.0081	-0.1321	0.0081	-0.1085
c_{IC}	-0.0927	-0.0569	-0.0927	0.0603	-0.0927	0.0346
c_{CC}	-0.0483	-0.0363	-0.0483	0.0032	-0.0483	-0.0055
gh_I	-0.0256	-0.0420	0.4609	0.3910	0.3539	0.2959
gh_C	-0.0820	-0.0690	-0.4146	-0.3591	-0.3415	-0.2953
j_I	-0.0050	-0.0308	-0.0050	-0.1152	-0.0050	-0.0966
j_C	-0.0632	-0.0432	-0.0632	0.0223	-0.0632	0.0079
πh_I	-0.0543	-0.0563	-0.0543	-0.0632	-0.0543	-0.0617
πh_C	-0.0305	-0.0264	-0.0305	-0.0130	-0.0305	-0.0159
y_I	-0.0543	-0.0500	-0.0543	-0.0360	-0.0543	-0.0390
y_C	-0.0305	-0.0347	-0.0305	-0.0483	-0.0305	-0.0453
l_I	0.0000	0.0064	0.0000	0.0272	0.0000	0.0226
l_C	0.0000	-0.0083	0.0000	-0.0354	0.0000	-0.0294
r_{KI}	-0.0396	-0.0405	-0.0396	-0.0436	-0.0396	-0.0429
r_{KC}	-0.0396	-0.0405	-0.0396	-0.0436	-0.0396	-0.0429
k_I	-0.0147	-0.0094	-0.0147	0.0076	-0.0147	0.0039
k_C	0.0091	0.0059	0.0091	-0.0047	0.0091	-0.0024
r_{EI}	0.9580	0.9579	0.9580	0.9577	0.9580	0.9577
r_{EC}	0.9580	0.9579	0.9580	0.9577	0.9580	0.9577
e_I	-1.0123	-1.0079	-1.0123	-0.9936	-1.0123	-0.9968
e_C	-0.9885	-0.9926	-0.9885	-1.0060	-0.9885	-1.0030
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0500	-0.0543	-0.0360	-0.0543	-0.0390
πf_C	-0.0305	-0.0347	-0.0305	-0.0483	-0.0305	-0.0453
w_I	-0.0543	-0.0563	-0.0543	-0.0632	-0.0543	-0.0617
w_C	-0.0305	-0.0264	-0.0305	-0.0130	-0.0305	-0.0159
p	0.1008	0.0469	0.1008	-0.1298	0.1008	-0.0910
grh_I	0.0017	-0.0241	1.1488	1.0383	1.1488	1.0569
grf_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
grh_C	-0.0948	-0.0659	-0.0948	0.0286	0.4002	0.5028
grf_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
gc_I	-0.0712	-0.0717	-0.6862	-0.6883	-0.9715	-0.9733
gc_C	-0.0712	-0.0717	-0.6862	-0.6883	-0.9715	-0.9733
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
tr_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000

Appendix5: Sensitivity Test 3, Full Simulation Results For An Increase in TFP

Variable	Base Case		Base Case +TFP Increase in Interior		Base Case +TFP Increase in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0142	-0.0354	-1.1405	-0.0466	1.0313	1.0515
v_C	-0.0697	-0.0500	1.7226	0.7093	1.0842	1.0655
c_{II}	-0.0363	-0.0453	0.1601	0.6275	0.9638	0.9724
c_{CI}	0.0081	-0.0247	-2.2897	-0.5972	1.0081	1.0393
c_{IC}	-0.0927	-0.0569	3.2781	1.4304	0.9073	0.8732
c_{CC}	-0.0483	-0.0363	0.8282	0.2057	0.9517	0.9402
gh_I	-0.0256	-0.0420	-0.8090	0.0343	1.1815	1.1970
gh_C	-0.0820	-0.0690	1.4272	0.7567	1.6027	1.5903
j_I	-0.0050	-0.0308	-1.5654	-0.2351	0.9950	1.0195
j_C	-0.0632	-0.0432	1.6491	0.6160	0.9368	0.9177
πh_I	-0.0543	-0.0563	1.1547	1.2626	0.9458	0.9477
πh_C	-0.0305	-0.0264	-0.1573	-0.3692	0.9695	0.9656
y_I	-0.0543	-0.0500	1.1547	0.9338	0.9458	0.9417
y_C	-0.0305	-0.0347	-0.1573	0.0579	0.9695	0.9735
l_I	0.0000	0.0064	0.0000	-0.3288	0.0000	-0.0061
l_C	0.0000	-0.0083	0.0000	0.4271	0.0000	0.0079
r_{KI}	-0.0396	-0.0405	0.3449	0.3932	0.9604	0.9613
r_{KC}	-0.0396	-0.0405	0.3449	0.3932	0.9604	0.9613
k_I	-0.0147	-0.0094	0.8097	0.5406	-0.0147	-0.0196
k_C	0.0091	0.0059	-0.5022	-0.3353	0.0091	0.0122
r_{EI}	0.9580	0.9579	1.4770	1.4814	1.9580	1.9581
r_{EC}	0.9580	0.9579	1.4770	1.4814	1.9580	1.9581
e_I	-1.0123	-1.0079	-0.3223	-0.5475	-1.0123	-1.0164
e_C	-0.9885	-0.9926	-1.6342	-1.4234	-0.9885	-0.9846
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0500	1.1547	0.9338	0.9458	0.9417
πf_C	-0.0305	-0.0347	-0.1573	0.0579	0.9695	0.9735
w_I	-0.0543	-0.0563	1.1547	1.2626	0.9458	0.9477
w_C	-0.0305	-0.0264	-0.1573	-0.3692	0.9695	0.9656
p	0.1008	0.0469	-5.5678	-2.7834	0.1008	0.1522
grh_I	0.0017	-0.0241	-1.5529	-0.2189	0.7931	0.8177
grf_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
grh_C	-0.0948	-0.0659	2.5996	1.1101	1.3361	1.3086
grf_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
gc_I	-0.0712	-0.0717	0.4313	0.4565	1.8291	1.8296
gc_C	-0.0712	-0.0717	0.4313	0.4565	1.8291	1.8296
d_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
d_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 4, Full Simulation Results for a Cut in Tax (elasticity is 0.20)

Variable	Base Case		Base Case+ Tax Cut in Interior		Base Case +Tax Cut in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.1447	-0.0220	0.1601	-0.0899	-0.2872	0.0102
v_C	0.0411	-0.0589	-0.2184	-0.0147	0.1630	-0.0794
c_{II}	-0.1201	-0.0297	0.1674	-0.0169	-0.1711	0.0481
c_{CI}	-0.1718	-0.0116	0.2856	-0.0407	-0.3045	0.0838
c_{IC}	0.0864	-0.0651	-0.3057	0.0031	0.3624	-0.0050
c_{CC}	0.0348	-0.0470	-0.1875	-0.0207	0.2290	0.0307
gh_I	-0.1275	-0.0312	-0.1047	-0.3010	-0.4299	-0.1964
gh_C	-0.0086	-0.0750	-0.1621	-0.0266	-0.2488	-0.4099
j_I	-0.1649	-0.0140	0.2699	-0.0376	-0.2867	0.0790
j_C	0.0481	-0.0517	-0.2179	-0.0146	0.2633	0.0215
πh_I	-0.0543	-0.0595	0.0165	0.0272	-0.0007	-0.0135
πh_C	-0.0305	-0.0202	-0.0379	-0.0590	0.0619	0.0870
y_I	-0.0543	-0.0435	-0.0420	-0.0640	-0.0592	-0.0330
y_C	-0.0305	-0.0410	-0.0379	-0.0165	-0.0275	-0.0530
l_I	0.0000	0.0161	0.0000	-0.0327	0.0000	0.0389
l_C	0.0000	-0.0209	0.0000	0.0425	0.0000	-0.0506
r_{KI}	-0.0396	-0.0420	-0.0171	-0.0123	0.0363	0.0306
r_{KC}	-0.0396	-0.0420	-0.0171	-0.0123	0.0363	0.0306
k_I	-0.0147	-0.0015	0.0336	0.0068	-0.0370	-0.0051
k_C	0.0091	0.0009	-0.0208	-0.0042	0.0230	0.0032
r_{EI}	0.9580	0.9578	0.9884	0.9888	1.0157	1.0151
r_{EC}	0.9580	0.9578	0.9884	0.9888	1.0157	1.0151
e_I	-1.0123	-1.0013	-0.9719	-0.9943	-1.0164	-0.9897
e_C	-0.9885	-0.9988	-1.0263	-1.0053	-0.9847	-1.0097
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0435	0.0165	-0.0055	-0.0007	0.0255
πf_C	-0.0305	-0.0410	-0.0379	-0.0165	0.0619	0.0364
w_I	-0.0543	-0.0595	0.0165	0.0272	-0.0007	-0.0135
w_C	-0.0305	-0.0202	-0.0379	-0.0590	0.0593	0.0844
p	-0.2582	0.0904	0.5913	-0.1191	-0.6669	0.1783
grh_I	-0.1513	-0.0099	-0.1652	-0.4533	-0.7069	-0.3641
grf_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
grh_C	0.0846	-0.0848	-0.3481	-0.0028	-0.5794	-0.9903
grf_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
gc_I	-0.0877	-0.0666	-0.0040	-0.0469	0.0321	0.0832
gc_C	-0.0877	-0.0666	-0.0040	-0.0469	0.0321	0.0832
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	-1.0000	-1.0000	-1.0000	-1.0000
t_C	0.0000	0.0000	0.0000	0.0000	-1.0000	-1.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 4, Full Simulation Results for An Increase in Infrastructure (elasticity is 0.20)

Variable	Base Case		Base Case +Infrastructure Increase in Interior		Base Case +Infrastructure Increase in two Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.1447	-0.0220	0.5728	-0.1777	0.1198	-0.0709
v_C	0.0411	-0.0589	-0.5635	0.0482	-0.1689	-0.0135
c_{II}	-0.1201	-0.0297	0.5496	-0.0036	0.2063	0.0658
c_{CI}	-0.1718	-0.0116	0.8938	-0.0859	0.2959	0.0469
c_{IC}	0.0864	-0.0651	-0.8271	0.0999	-0.1517	0.0839
c_{CC}	0.0348	-0.0470	-0.4829	0.0176	-0.0622	0.0650
gh_I	-0.1275	-0.0312	-0.0402	-0.6293	-0.3680	-0.5177
gh_C	-0.0086	-0.0750	-0.3662	0.0404	-0.4136	-0.3103
j_I	-0.1649	-0.0140	0.8479	-0.0750	0.2839	0.0494
j_C	0.0481	-0.0517	-0.5715	0.0387	-0.0852	0.0699
πh_I	-0.0543	-0.0595	0.1105	0.1427	0.0921	0.1003
πh_C	-0.0305	-0.0202	-0.0478	-0.1111	0.0510	0.0349
y_I	-0.0543	-0.0435	0.1105	0.0445	0.0921	0.0754
y_C	-0.0305	-0.0410	-0.0478	0.0166	0.0510	0.0673
l_I	0.0000	0.0161	0.0000	-0.0983	0.0000	-0.0250
l_C	0.0000	-0.0209	0.0000	0.1277	0.0000	0.0324
r_{KI}	-0.0396	-0.0420	0.0128	0.0272	0.0668	0.0704
r_{KC}	-0.0396	-0.0420	0.0128	0.0272	0.0668	0.0704
k_I	-0.0147	-0.0015	0.0977	0.0172	0.0254	0.0050
k_C	0.0091	0.0009	-0.0606	-0.0107	-0.0158	-0.0031
r_{EI}	0.9580	0.9578	1.0287	1.0300	1.0709	1.0712
r_{EC}	0.9580	0.9578	1.0287	1.0300	1.0709	1.0712
e_I	-1.0123	-1.0013	-0.9183	-0.9856	-0.9787	-0.9959
e_C	-0.9885	-0.9988	-1.0765	-1.0135	-1.0199	-1.0039
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0435	0.1105	0.0445	0.0921	0.0754
πf_C	-0.0305	-0.0410	-0.0478	0.0166	0.0510	0.0673
w_I	-0.0543	-0.0595	0.1105	0.1427	0.0921	0.1003
w_C	-0.0305	-0.0202	-0.0478	-0.1111	0.0510	0.0349
p	-0.2582	0.0904	1.7209	-0.4118	0.4475	-0.0944
grh_I	-0.1513	-0.0099	-0.1287	-0.9938	-0.6777	-0.8975
grf_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
grh_C	0.0846	-0.0848	-0.9236	0.1133	-1.0753	-0.8118
grf_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
gc_I	-0.0877	-0.0666	0.1074	-0.0215	0.1484	0.1157
gc_C	-0.0877	-0.0666	0.1074	-0.0215	0.1484	0.1157
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity 4, Full Simulation Results for Transfer to Infrastructure (elasticity is 0.20)

Variable	Base Case		Base Case +Transfer to Infrastructure in Interior		Base Case +Transfer to Infrastructure Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.1447	-0.0220	-0.9906	-0.1646	-0.6731	-0.1195
v_C	0.0411	-0.0589	0.7926	0.0570	0.5220	0.0290
c_{II}	-0.1201	-0.0297	-0.8660	-0.0692	-0.5461	-0.0121
c_{CI}	-0.1718	-0.0116	-1.4519	-0.2046	-0.9440	-0.1080
c_{IC}	0.0864	-0.0651	1.4780	0.2507	1.0458	0.2233
c_{CC}	0.0348	-0.0470	0.8920	0.1153	0.6479	0.1273
gh_I	-0.1275	-0.0312	-0.2494	-0.2296	-0.3203	-0.3071
gh_C	-0.0086	-0.0750	-0.3597	-0.3311	-0.4620	-0.4429
j_I	-0.1649	-0.0140	-1.3738	-0.1866	-0.8910	-0.0953
j_C	0.0481	-0.0517	1.0427	0.1501	0.7502	0.1520
πh_I	-0.0543	-0.0595	-0.1183	0.1439	-0.0383	0.1375
πh_C	-0.0305	-0.0202	0.1512	-0.0799	0.1447	-0.0102
y_I	-0.0543	-0.0435	-0.1183	0.0475	-0.0383	0.0729
y_C	-0.0305	-0.0410	0.1512	0.0453	0.1447	0.0737
l_I	0.0000	0.0161	0.0000	-0.0964	0.0000	-0.0646
l_C	0.0000	-0.0209	0.0000	0.1252	0.0000	0.0839
r_{KI}	-0.0396	-0.0420	0.0480	0.0461	0.0747	0.0734
r_{KC}	-0.0396	-0.0420	0.0480	0.0461	0.0747	0.0734
k_I	-0.0147	-0.0015	-0.1663	0.0014	-0.1129	-0.0006
k_C	0.0091	0.0009	0.1031	-0.0009	0.0700	0.0003
r_{EI}	0.9580	0.9578	1.0209	1.0464	1.0563	1.0733
r_{EC}	0.9580	0.9578	1.0209	1.0464	1.0563	1.0733
e_I	-1.0123	-1.0013	-1.1392	-0.9988	-1.0945	-1.0005
e_C	-0.9885	-0.9988	-0.8698	-1.0011	-0.9116	-0.9996
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0435	-0.1183	0.0475	-0.0383	0.0729
πf_C	-0.0305	-0.0410	0.1512	0.0453	0.1447	0.0737
w_I	-0.0543	-0.0595	-0.1183	0.1439	-0.0383	0.1375
w_C	-0.0305	-0.0202	0.1512	-0.0799	0.1447	-0.0102
p	-0.2582	0.0904	-2.9299	-0.6768	-1.9898	-0.4798
grh_I	-0.1513	-0.0099	0.0000	0.0000	0.0000	0.0000
grf_I	0.0000	0.0000	-0.1878	1.0457	0.3001	1.1268
grh_C	0.0846	-0.0848	0.0000	0.0000	0.0000	0.0000
grf_C	0.0000	0.0000	1.8062	0.3114	1.8263	0.8244
gc_I	-0.0877	-0.0666	-0.6652	-0.6124	-0.8545	-0.8191
gc_C	-0.0877	-0.0666	-0.6652	-0.6124	-0.8545	-0.8191
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
tr_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000

Appendix5: Sensitivity Test 5, Full Simulation Results for a Cut in Tax (elasticity is 0.68)

Variable	Base Case		Base Case+ Tax Cut in Interior		Base Case +Tax Cut in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0355	-0.0401	-0.0899	-0.0661	-0.0053	-0.0255
v_C	-0.0516	-0.0469	-0.0062	-0.0305	-0.0763	-0.0557
c_{II}	-0.0500	-0.0508	0.0066	0.0108	0.0102	0.0066
c_{CI}	-0.0213	-0.0293	-0.0591	-0.0175	0.0842	0.0490
c_{IC}	-0.0634	-0.0540	0.0375	-0.0115	-0.0247	0.0169
c_{CC}	-0.0348	-0.0325	-0.0282	-0.0398	0.0494	0.0593
gh_I	-0.0423	-0.0457	-0.2999	-0.2818	-0.2098	-0.2251
gh_C	-0.0700	-0.0670	-0.0212	-0.0372	-0.4076	-0.3940
j_I	-0.0311	-0.0366	-0.0365	-0.0078	0.0588	0.0344
j_C	-0.0450	-0.0402	-0.0047	-0.0297	0.0229	0.0441
πh_I	-0.0543	-0.0552	0.0165	0.0215	-0.0007	-0.0050
πh_C	-0.0305	-0.0286	-0.0379	-0.0479	0.0619	0.0704
y_I	-0.0543	-0.0523	-0.0420	-0.0524	-0.0592	-0.0504
y_C	-0.0305	-0.0325	-0.0379	-0.0278	-0.0275	-0.0361
l_I	0.0000	0.0030	0.0000	-0.0155	0.0000	0.0131
l_C	0.0000	-0.0039	0.0000	0.0201	0.0000	-0.0171
r_{KI}	-0.0396	-0.0400	-0.0171	-0.0148	0.0363	0.0344
r_{KC}	-0.0396	-0.0400	-0.0171	-0.0148	0.0363	0.0344
k_I	-0.0147	-0.0122	0.0336	0.0209	-0.0370	-0.0263
k_C	0.0091	0.0076	-0.0208	-0.0130	0.0230	0.0163
r_{EI}	0.9580	0.9580	0.9884	0.9886	1.0157	1.0155
r_{EC}	0.9580	0.9580	0.9884	0.9886	1.0157	1.0155
e_I	-1.0123	-1.0102	-0.9719	-0.9825	-1.0164	-1.0074
e_C	-0.9885	-0.9904	-1.0263	-1.0164	-0.9847	-0.9931
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0523	0.0165	0.0060	-0.0007	0.0081
πf_C	-0.0305	-0.0325	-0.0379	-0.0278	0.0619	0.0533
w_I	-0.0543	-0.0552	0.0165	0.0215	-0.0007	-0.0050
w_C	-0.0305	-0.0286	-0.0379	-0.0479	0.0593	0.0677
p	0.0422	0.0316	-0.0965	-0.0416	0.1089	0.0623
grh_I	-0.0233	-0.0291	-0.4584	-0.4280	-0.3762	-0.4020
grf_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
grh_C	-0.0655	-0.0593	-0.0043	-0.0363	-0.9672	-0.9400
grf_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
gc_I	-0.0739	-0.0734	-0.0356	-0.0380	0.0678	0.0698
gc_C	-0.0739	-0.0734	-0.0356	-0.0380	0.0678	0.0698
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	-1.0000	-1.0000	-1.0000	-1.0000
t_C	0.0000	0.0000	0.0000	0.0000	-1.0000	-1.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 5, Full Simulation Results for An Increase in Infrastructure (elasticity is 0.68)

Variable	Base Case		Base Case +Infrastructure Increase in Interior		Base Case +Infrastructure Increase in two Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0355	-0.0401	-0.1547	-0.0953	-0.0693	-0.0520
v_C	-0.0516	-0.0469	0.0540	-0.0064	-0.0083	-0.0260
c_{II}	-0.0500	-0.0508	0.0818	0.0922	0.0847	0.0878
c_{CI}	-0.0213	-0.0293	-0.1093	-0.0057	0.0350	0.0653
c_{IC}	-0.0634	-0.0540	0.1717	0.0494	0.1081	0.0723
c_{CC}	-0.0348	-0.0325	-0.0194	-0.0485	0.0584	0.0499
gh_I	-0.0423	-0.0457	-0.6082	-0.5630	-0.5157	-0.5025
gh_C	-0.0700	-0.0670	0.0436	0.0038	-0.3071	-0.3187
j_I	-0.0311	-0.0366	-0.0437	0.0280	0.0521	0.0730
j_C	-0.0450	-0.0402	0.0490	-0.0134	0.0762	0.0579
πh_I	-0.0543	-0.0552	0.1105	0.1232	0.0921	0.0959
πh_C	-0.0305	-0.0286	-0.0478	-0.0727	0.0510	0.0437
y_I	-0.0543	-0.0523	0.1105	0.0845	0.0921	0.0846
y_C	-0.0305	-0.0325	-0.0478	-0.0225	0.0510	0.0584
l_I	0.0000	0.0030	0.0000	-0.0387	0.0000	-0.0113
l_C	0.0000	-0.0039	0.0000	0.0502	0.0000	0.0147
r_{KI}	-0.0396	-0.0400	0.0128	0.0185	0.0668	0.0684
r_{KC}	-0.0396	-0.0400	0.0128	0.0185	0.0668	0.0684
k_I	-0.0147	-0.0122	0.0977	0.0660	0.0254	0.0161
k_C	0.0091	0.0076	-0.0606	-0.0410	-0.0158	-0.0100
r_{EI}	0.9580	0.9580	1.0287	1.0292	1.0709	1.0710
r_{EC}	0.9580	0.9580	1.0287	1.0292	1.0709	1.0710
e_I	-1.0123	-1.0102	-0.9183	-0.9448	-0.9787	-0.9865
e_C	-0.9885	-0.9904	-1.0765	-1.0517	-1.0199	-1.0126
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0523	0.1105	0.0845	0.0921	0.0846
πf_C	-0.0305	-0.0325	-0.0478	-0.0225	0.0510	0.0584
w_I	-0.0543	-0.0552	0.1105	0.1232	0.0921	0.0959
w_C	-0.0305	-0.0286	-0.0478	-0.0727	0.0510	0.0437
p	0.0422	0.0316	-0.2810	-0.1440	-0.0731	-0.0330
grh_I	-0.0233	-0.0291	-0.9820	-0.9063	-0.8996	-0.8775
grf_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
grh_C	-0.0655	-0.0593	0.0771	-0.0029	-0.8151	-0.8385
grf_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
gc_I	-0.0739	-0.0734	0.0153	0.0095	0.1245	0.1228
gc_C	-0.0739	-0.0734	0.0153	0.0095	0.1245	0.1228
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 5, Full Simulation Results for Transfer to Infrastructure (elasticity is 0.68)

Variable	Base Case		Base Case +Transfer to Infrastructure in Interior		Base Case +Transfer to Infrastructure Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0355	-0.0401	-0.0596	-0.0472	-0.0409	-0.0363
v_C	-0.0516	-0.0469	-0.0086	-0.0221	-0.0222	-0.0271
c_{II}	-0.0500	-0.0508	0.1061	0.1117	0.1141	0.1161
c_{CI}	-0.0213	-0.0293	-0.1086	-0.0844	-0.0317	-0.0229
c_{IC}	-0.0634	-0.0540	0.2072	0.1789	0.1827	0.1724
c_{CC}	-0.0348	-0.0325	-0.0076	-0.0172	0.0369	0.0334
gh_I	-0.0423	-0.0457	-0.2140	-0.2149	-0.2963	-0.2966
gh_C	-0.0700	-0.0670	-0.3087	-0.3099	-0.4274	-0.4278
j_I	-0.0311	-0.0366	-0.0349	-0.0171	0.0184	0.0249
j_C	-0.0450	-0.0402	0.0693	0.0530	0.0891	0.0831
πh_I	-0.0543	-0.0552	0.1383	0.1457	0.1360	0.1387
πh_C	-0.0305	-0.0286	-0.0395	-0.0491	0.0152	0.0117
y_I	-0.0543	-0.0523	0.1383	0.1348	0.1360	0.1347
y_C	-0.0305	-0.0325	-0.0395	-0.0349	0.0152	0.0169
l_I	0.0000	0.0030	0.0000	-0.0109	0.0000	-0.0040
l_C	0.0000	-0.0039	0.0000	0.0142	0.0000	0.0052
r_{KI}	-0.0396	-0.0400	0.0286	0.0300	0.0615	0.0620
r_{KC}	-0.0396	-0.0400	0.0286	0.0300	0.0615	0.0620
k_I	-0.0147	-0.0122	0.1098	0.1047	0.0746	0.0727
k_C	0.0091	0.0076	-0.0681	-0.0650	-0.0462	-0.0451
r_{EI}	0.9580	0.9580	1.0465	1.0471	1.0736	1.0738
r_{EC}	0.9580	0.9580	1.0465	1.0471	1.0736	1.0738
e_I	-1.0123	-1.0102	-0.9081	-0.9124	-0.9376	-0.9392
e_C	-0.9885	-0.9904	-1.0860	-1.0820	-1.0584	-1.0569
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0543	-0.0523	0.1383	0.1348	0.1360	0.1347
πf_C	-0.0305	-0.0325	-0.0395	-0.0349	0.0152	0.0169
w_I	-0.0543	-0.0552	0.1383	0.1457	0.1360	0.1387
w_C	-0.0305	-0.0286	-0.0395	-0.0491	0.0152	0.0117
p	0.0422	0.0316	-0.3158	-0.2883	-0.2145	-0.2044
grh_I	-0.0233	-0.0291	0.0000	0.0000	0.0000	0.0000
grf_I	0.0000	0.0000	1.1821	1.2024	1.2304	1.2379
grh_C	-0.0655	-0.0593	0.0000	0.0000	0.0000	0.0000
grf_C	0.0000	0.0000	0.1155	0.0935	0.6780	0.6700
gc_I	-0.0739	-0.0734	-0.5710	-0.5732	-0.7905	-0.7913
gc_C	-0.0739	-0.0734	-0.5710	-0.5732	-0.7905	-0.7913
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
tr_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000

Appendix5: Sensitivity Test 6, Full Simulation Results for a Cut in Tax (Alternative Definition of Regions)

Variable	Base Case		Base Case+ Tax Cut in Interior		Base Case +Tax Cut in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	0.0253	-0.0304	-0.1425	-0.0648	0.1355	-0.0076
v_C	-0.1515	-0.0621	0.1043	-0.0205	-0.3189	-0.0891
c_{II}	-0.0301	-0.0479	-0.0181	0.0067	0.0590	0.0133
c_{CI}	0.1398	0.0080	-0.2004	-0.0165	0.4554	0.1167
c_{IC}	-0.2463	-0.0873	0.2140	-0.0080	-0.4456	-0.0369
c_{CC}	-0.0764	-0.0314	0.0317	-0.0312	-0.0492	0.0666
gh_I	0.0320	-0.0308	-0.3771	-0.2895	-0.0336	-0.1949
gh_C	-0.1764	-0.0912	0.1031	-0.0158	-0.7058	-0.4868
j_I	0.0838	-0.0104	-0.1402	-0.0088	0.3246	0.0826
j_C	-0.1941	-0.0701	0.1579	-0.0151	-0.3237	-0.0051
πh_I	-0.0567	-0.0601	0.0104	0.0153	-0.0029	-0.0118
πh_C	-0.0195	-0.0087	-0.0294	-0.0445	0.0850	0.1128
y_I	-0.0567	-0.0503	-0.0481	-0.0570	-0.0614	-0.0451
y_C	-0.0195	-0.0306	-0.0294	-0.0140	-0.0140	-0.0424
l_I	0.0000	0.0099	0.0000	-0.0137	0.0000	0.0253
l_C	0.0000	-0.0219	0.0000	0.0305	0.0000	-0.0562
r_{KI}	-0.0401	-0.0415	-0.0073	-0.0054	0.0352	0.0316
r_{KC}	-0.0401	-0.0415	-0.0073	-0.0054	0.0352	0.0316
k_I	-0.0165	-0.0088	0.0178	0.0069	-0.0380	-0.0181
k_C	0.0206	0.0109	-0.0221	-0.0086	0.0473	0.0225
r_{EI}	0.9539	0.9553	0.9991	0.9971	1.0106	1.0143
r_{EC}	0.9539	0.9553	0.9991	0.9971	1.0106	1.0143
e_I	-1.0106	-1.0056	-0.9887	-0.9956	-1.0135	-1.0008
e_C	-0.9734	-0.9859	-1.0285	-1.0111	-0.9661	-0.9981
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0567	-0.0503	0.0104	0.0015	-0.0029	0.0135
πf_C	-0.0195	-0.0306	-0.0294	-0.0140	0.0850	0.0566
w_I	-0.0567	-0.0601	0.0104	0.0153	-0.0029	-0.0118
w_C	-0.0195	-0.0087	-0.0294	-0.0445	0.0825	0.1103
p	0.3861	0.1270	-0.4143	-0.0528	0.9009	0.2351
grh_I	0.0924	-0.0057	-0.6273	-0.4904	-0.1550	-0.4072
grf_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
grh_C	-0.3205	-0.1217	0.2684	-0.0089	-1.6446	-1.1340
grf_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
gc_I	-0.0485	-0.0641	-0.0437	-0.0219	0.1281	0.0880
gc_C	-0.0485	-0.0641	-0.0437	-0.0219	0.1281	0.0880
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	-1.0000	-1.0000	-1.0000	-1.0000
t_C	0.0000	0.0000	0.0000	0.0000	-1.0000	-1.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 6, Full Simulation Results for An Increase in Infrastructure (Alternative Regions)

Variable	Base Case		Base Case +Infrastructure Increase in Interior		Base Case +Infrastructure Increase in two Regions	
	SR	LR	SR	LR	SR	LR
v_I	0.0253	-0.0304	-0.3049	-0.0948	-0.0378	-0.0368
v_C	-0.1515	-0.0621	0.3622	0.0249	-0.0348	-0.0363
c_{II}	-0.0301	-0.0479	-0.0059	0.0611	0.0676	0.0679
c_{CI}	0.1398	0.0080	-0.5434	-0.0463	0.0866	0.0888
c_{IC}	-0.2463	-0.0873	0.6781	0.0782	0.0434	0.0407
c_{CC}	-0.0764	-0.0314	0.1406	-0.0292	0.0624	0.0616
gh_I	0.0320	-0.0308	-0.7589	-0.5221	-0.4276	-0.4265
gh_C	-0.1764	-0.0912	0.3850	0.0636	-0.3465	-0.3479
j_I	0.0838	-0.0104	-0.3661	-0.0109	0.0803	0.0819
j_C	-0.1941	-0.0701	0.5129	0.0451	0.0492	0.0471
πh_I	-0.0567	-0.0601	0.0781	0.0912	0.0646	0.0647
πh_C	-0.0195	-0.0087	-0.0394	-0.0802	0.0688	0.0686
y_I	-0.0567	-0.0503	0.0781	0.0541	0.0646	0.0645
y_C	-0.0195	-0.0306	-0.0394	0.0023	0.0688	0.0690
l_I	0.0000	0.0099	0.0000	-0.0372	0.0000	-0.0002
l_C	0.0000	-0.0219	0.0000	0.0825	0.0000	0.0004
r_{KI}	-0.0401	-0.0415	0.0257	0.0310	0.0665	0.0665
r_{KC}	-0.0401	-0.0415	0.0257	0.0310	0.0665	0.0665
k_I	-0.0165	-0.0088	0.0523	0.0231	-0.0019	-0.0020
k_C	0.0206	0.0109	-0.0651	-0.0287	0.0023	0.0025
r_{EI}	0.9539	0.9553	1.0446	1.0393	1.0658	1.0658
r_{EC}	0.9539	0.9553	1.0446	1.0393	1.0658	1.0658
e_I	-1.0106	-1.0056	-0.9666	-0.9853	-1.0012	-1.0013
e_C	-0.9734	-0.9859	-1.0840	-1.0370	-0.9970	-0.9968
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0567	-0.0503	0.0781	0.0541	0.0646	0.0645
πf_C	-0.0195	-0.0306	-0.0394	0.0023	0.0688	0.0690
w_I	-0.0567	-0.0601	0.0781	0.0912	0.0646	0.0647
w_C	-0.0195	-0.0087	-0.0394	-0.0802	0.0688	0.0686
p	0.3861	0.1270	-1.2215	-0.2441	0.0433	0.0476
grh_I	0.0924	-0.0057	-1.2994	-0.9292	-0.8458	-0.8441
grf_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
grh_C	-0.3205	-0.1217	0.8622	0.1126	-0.8823	-0.8856
grf_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
gc_I	-0.0485	-0.0641	-0.0388	0.0201	0.1294	0.1297
gc_C	-0.0485	-0.0641	-0.0388	0.0201	0.1294	0.1297
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 6, Full Simulation Results for Transfer to Infrastructure (Alternative Regions)

Variable	Base Case		Base Case +Transfer to Infrastructure in Interior		Base Case +Transfer to Infrastructure Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	0.0253	-0.0304	-0.1029	-0.0629	-0.0687	-0.0481
v_C	-0.1515	-0.0621	0.0755	0.0042	0.0230	-0.0137
c_{II}	-0.0301	-0.0479	0.0281	0.0547	0.0553	0.0689
c_{CI}	0.1398	0.0080	-0.2241	-0.1203	-0.0883	-0.0350
c_{IC}	-0.2463	-0.0873	0.3491	0.2104	0.2380	0.1667
c_{CC}	-0.0764	-0.0314	0.0969	0.0354	0.0944	0.0628
gh_I	0.0320	-0.0308	-0.2834	-0.2818	-0.3442	-0.3434
gh_C	-0.1764	-0.0912	-0.3500	-0.3480	-0.4251	-0.4241
j_I	0.0838	-0.0104	-0.1409	-0.0626	-0.0410	-0.0007
j_C	-0.1941	-0.0701	0.2716	0.1566	0.1938	0.1347
πh_I	-0.0567	-0.0601	0.0675	0.0895	0.0777	0.0890
πh_C	-0.0195	-0.0087	0.0124	-0.0317	0.0463	0.0236
y_I	-0.0567	-0.0503	0.0675	0.0687	0.0777	0.0783
y_C	-0.0195	-0.0306	0.0124	0.0146	0.0463	0.0474
l_I	0.0000	0.0099	0.0000	-0.0208	0.0000	-0.0107
l_C	0.0000	-0.0219	0.0000	0.0463	0.0000	0.0238
r_{KI}	-0.0401	-0.0415	0.0430	0.0446	0.0637	0.0645
r_{KC}	-0.0401	-0.0415	0.0430	0.0446	0.0637	0.0645
k_I	-0.0165	-0.0088	0.0246	0.0241	0.0140	0.0138
k_C	0.0206	0.0109	-0.0306	-0.0300	-0.0174	-0.0171
r_{EI}	0.9539	0.9553	1.0519	1.0533	1.0688	1.0695
r_{EC}	0.9539	0.9553	1.0519	1.0533	1.0688	1.0695
e_I	-1.0106	-1.0056	-0.9843	-0.9846	-0.9911	-0.9912
e_C	-0.9734	-0.9859	-1.0394	-1.0387	-1.0225	-1.0221
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0567	-0.0503	0.0675	0.0687	0.0777	0.0783
πf_C	-0.0195	-0.0306	0.0124	0.0146	0.0463	0.0474
w_I	-0.0567	-0.0601	0.0675	0.0895	0.0777	0.0890
w_C	-0.0195	-0.0087	0.0124	-0.0317	0.0463	0.0236
p	0.3861	0.1270	-0.5732	-0.3978	-0.3263	-0.2361
grh_I	0.0924	-0.0057	0.0000	0.0000	0.0000	0.0000
grf_I	0.0000	0.0000	0.9691	1.0598	1.0777	1.1243
grh_C	-0.3205	-0.1217	0.0000	0.0000	0.0000	0.0000
grf_C	0.0000	0.0000	0.4733	0.2938	0.8066	0.7144
gc_I	-0.0485	-0.0641	-0.6608	-0.6571	-0.8027	-0.8008
gc_C	-0.0485	-0.0641	-0.6608	-0.6571	-0.8027	-0.8008
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
tr_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000

Appendix5: Sensitivity Test 7, Full Simulation Results for a Cut in Tax (Government Allocation)

Variable	Base Case		Base Case+ Tax Cut in Interior		Base Case +Tax Cut in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0539	-0.0465	0.1293	0.0090	0.0096	-0.0271
v_C	-0.0343	-0.0412	-0.1878	-0.0762	-0.0872	-0.0531
c_{II}	-0.0410	-0.0378	0.0287	-0.0236	0.0408	0.0248
c_{CI}	-0.0616	-0.0502	0.2156	0.0300	0.0895	0.0329
c_{IC}	-0.0147	-0.0272	-0.2091	-0.0067	-0.0213	0.0405
c_{CC}	-0.0354	-0.0396	-0.0223	0.0470	0.0275	0.0486
gh_I	-0.0579	-0.0522	0.1090	0.0164	-0.1995	-0.2278
gh_C	-0.0593	-0.0638	-0.5011	-0.4272	-0.4155	-0.3930
j_I	-0.0555	-0.0465	0.1603	0.0142	0.0751	0.0305
j_C	-0.0284	-0.0354	-0.0849	0.0290	0.0111	0.0459
πh_I	-0.0326	-0.0318	-0.0469	-0.0607	0.0212	0.0170
πh_C	-0.0437	-0.0452	0.0544	0.0793	0.0486	0.0562
y_I	-0.0326	-0.0340	-0.0469	-0.0236	-0.0373	-0.0302
y_C	-0.0437	-0.0422	-0.0350	-0.0582	-0.0408	-0.0479
l_I	0.0000	-0.0023	0.0000	0.0371	0.0000	0.0113
l_C	0.0000	0.0030	0.0000	-0.0481	0.0000	-0.0147
r_{KI}	-0.0394	-0.0391	0.0140	0.0086	0.0365	0.0348
r_{KC}	-0.0394	-0.0391	0.0140	0.0086	0.0365	0.0348
k_I	0.0068	0.0051	-0.0609	-0.0322	-0.0153	-0.0065
k_C	-0.0042	-0.0031	0.0378	0.0200	0.0095	0.0040
r_{EI}	0.6409	0.6395	0.6266	0.6499	0.6947	0.7018
r_{EC}	1.2619	1.2633	1.3291	1.3058	1.3232	1.3161
e_I	-0.6735	-0.6735	-0.6735	-0.6735	-0.6735	-0.6735
e_C	-1.3056	-1.3056	-1.3056	-1.3056	-1.3056	-1.3056
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0326	-0.0340	-0.0469	-0.0236	0.0212	0.0283
πf_C	-0.0437	-0.0422	0.0544	0.0312	0.0486	0.0415
w_I	-0.0326	-0.0318	-0.0469	-0.0607	0.0212	0.0170
w_C	-0.0437	-0.0452	0.0518	0.0767	0.0460	0.0536
p	-0.0469	-0.0283	0.4247	0.1219	0.1108	0.0184
grh_I	-0.0466	-0.0375	0.1509	0.0042	-0.3606	-0.4054
grf_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
grh_C	-0.0387	-0.0488	-1.1369	-0.9733	-0.9861	-0.9361
grf_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
gc_I	-0.0768	-0.0767	0.0391	0.0366	0.0691	0.0684
gc_C	-0.0768	-0.0767	0.0391	0.0366	0.0691	0.0684
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	-1.0000	-1.0000
t_C	0.0000	0.0000	-1.0000	-1.0000	-1.0000	-1.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5:Sensitivity Test 7, Full Simulation Results for An Increase in Infrastructure(Government Allocation)

Variable	Base Case		Base Case +Infrastructure Increase in Interior		Base Case +Infrastructure Increase in two Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0539	-0.0465	0.1295	0.0122	-0.1420	-0.0673
v_C	-0.0343	-0.0412	-0.1795	-0.0708	0.0549	-0.0144
c_{II}	-0.0410	-0.0378	0.0286	-0.0224	0.0567	0.0892
c_{CI}	-0.0616	-0.0502	0.2150	0.0343	-0.0787	0.0365
c_{IC}	-0.0147	-0.0272	-0.2086	-0.0114	0.2290	0.1034
c_{CC}	-0.0354	-0.0396	-0.0222	0.0452	0.0936	0.0507
gh_I	-0.0579	-0.0522	0.1108	0.0206	-0.5736	-0.5161
gh_C	-0.0593	-0.0638	-0.4651	-0.3931	-0.2658	-0.3116
j_I	-0.0555	-0.0465	0.1599	0.0175	-0.0387	0.0521
j_C	-0.0284	-0.0354	-0.0847	0.0263	0.1390	0.0683
πh_I	-0.0326	-0.0318	-0.0471	-0.0605	0.1117	0.1202
πh_C	-0.0437	-0.0452	0.0528	0.0770	0.0392	0.0237
y_I	-0.0326	-0.0340	-0.0471	-0.0244	0.1117	0.0972
y_C	-0.0437	-0.0422	0.0528	0.0301	0.0392	0.0536
l_I	0.0000	-0.0023	0.0000	0.0361	0.0000	-0.0230
l_C	0.0000	0.0030	0.0000	-0.0469	0.0000	0.0299
r_{KI}	-0.0394	-0.0391	0.0146	0.0093	0.0669	0.0703
r_{KC}	-0.0394	-0.0391	0.0146	0.0093	0.0669	0.0703
k_I	0.0068	0.0051	-0.0616	-0.0336	0.0448	0.0269
k_C	-0.0042	-0.0031	0.0382	0.0209	-0.0278	-0.0167
r_{EI}	0.6409	0.6395	0.6265	0.6491	0.7852	0.7707
r_{EC}	1.2619	1.2633	1.3583	1.3357	1.3447	1.3592
e_I	-0.6735	-0.6735	-0.6735	-0.6735	-0.6735	-0.6735
e_C	-1.3056	-1.3056	-1.3056	-1.3056	-1.3056	-1.3056
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0326	-0.0340	-0.0471	-0.0244	0.1117	0.0972
πf_C	-0.0437	-0.0422	0.0528	0.0301	0.0392	0.0536
w_I	-0.0326	-0.0318	-0.0471	-0.0605	0.1117	0.1202
w_C	-0.0437	-0.0452	0.0528	0.0770	0.0392	0.0237
p	-0.0469	-0.0283	0.4237	0.1286	-0.3077	-0.1198
grh_I	-0.0466	-0.0375	0.1505	0.0075	-0.9864	-0.8953
grf_I	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
grh_C	-0.0387	-0.0488	-1.0653	-0.9058	-0.7138	-0.8153
grf_C	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
gc_I	-0.0768	-0.0767	0.0447	0.0424	0.1148	0.1163
gc_C	-0.0768	-0.0767	0.0447	0.0424	0.1148	0.1163
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 7, Full Simulation Results for Transfer to Infrastructure (Government Allocation)

Variable	Base Case		Base Case +Transfer to Infrastructure in Interior		Base Case +Transfer to Infrastructure Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0539	-0.0465	-0.0039	-0.0259	-0.1208	-0.0687
v_C	-0.0343	-0.0412	-0.0754	-0.0533	0.0480	-0.0040
c_{II}	-0.0410	-0.0378	-0.0081	-0.0231	0.0476	0.0832
c_{CI}	-0.0616	-0.0502	0.0537	0.0152	-0.1597	-0.0686
c_{IC}	-0.0147	-0.0272	-0.0867	-0.0444	0.3115	0.2117
c_{CC}	-0.0354	-0.0396	-0.0249	-0.0061	0.1042	0.0599
gh_I	-0.0579	-0.0522	-0.1139	-0.1133	-0.2996	-0.3010
gh_C	-0.0593	-0.0638	-0.1642	-0.1634	-0.4321	-0.4341
j_I	-0.0555	-0.0465	0.0355	0.0038	-0.0984	-0.0238
j_C	-0.0284	-0.0354	-0.0456	-0.0190	0.1737	0.1108
πh_I	-0.0326	-0.0318	-0.0331	-0.0436	0.1318	0.1566
πh_C	-0.0437	-0.0452	0.0000	0.0122	0.0208	-0.0082
y_I	-0.0326	-0.0340	-0.0331	-0.0317	0.1318	0.1285
y_C	-0.0437	-0.0422	0.0000	-0.0033	0.0208	0.0283
l_I	0.0000	-0.0023	0.0000	0.0119	0.0000	-0.0281
l_C	0.0000	0.0030	0.0000	-0.0155	0.0000	0.0365
r_{KI}	-0.0394	-0.0391	-0.0127	-0.0142	0.0633	0.0667
r_{KC}	-0.0394	-0.0391	-0.0127	-0.0142	0.0633	0.0667
k_I	0.0068	0.0051	-0.0204	-0.0176	0.0685	0.0618
k_C	-0.0042	-0.0031	0.0127	0.0109	-0.0425	-0.0383
r_{EI}	0.6409	0.6395	0.6404	0.6418	0.8053	0.8020
r_{EC}	1.2619	1.2633	1.3055	1.3023	1.3263	1.3339
e_I	-0.6735	-0.6735	-0.6735	-0.6735	-0.6735	-0.6735
e_C	-1.3056	-1.3056	-1.3056	-1.3056	-1.3056	-1.3056
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0326	-0.0340	-0.0331	-0.0317	0.1318	0.1285
πf_C	-0.0437	-0.0422	0.0000	-0.0033	0.0208	0.0283
w_I	-0.0326	-0.0318	-0.0331	-0.0436	0.1318	0.1566
w_C	-0.0437	-0.0452	0.0000	0.0122	0.0208	-0.0082
p	-0.0469	-0.0283	0.1404	0.0869	-0.4713	-0.3450
grh_I	-0.0466	-0.0375	0.0000	0.0000	0.0000	0.0000
grf_I	0.0000	0.0000	0.0383	0.0037	1.1110	1.1929
grh_C	-0.0387	-0.0488	0.0000	0.0000	0.0000	0.0000
grf_C	0.0000	0.0000	0.4576	0.4970	0.8249	0.7319
gc_I	-0.0768	-0.0767	-0.3038	-0.3022	-0.7991	-0.8028
gc_C	-0.0768	-0.0767	-0.3038	-0.3022	-0.7991	-0.8028
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
tr_C	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000

Appendix5: Sensitivity Test 8, Full Simulation Results for a Cut in Tax (Expenditure Maximizing)

Variable	Base Case		Base Case+ Tax Cut in Interior		Base Case +Tax Cut in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0282	-0.0385	-0.0268	-0.0389	-0.0384	-0.0463
v_C	-0.0588	-0.0489	-0.0630	-0.0513	-0.0622	-0.0545
c_{II}	-0.0435	-0.0495	-0.0447	-0.0517	-0.0502	-0.0549
c_{CI}	-0.0150	-0.0322	-0.0104	-0.0307	-0.0294	-0.0428
c_{IC}	-0.0798	-0.0611	-0.0882	-0.0661	-0.0768	-0.0622
c_{CC}	-0.0513	-0.0438	-0.0540	-0.0451	-0.0559	-0.0501
gh_I	-0.0316	-0.0343	-0.0325	-0.0357	-0.0384	-0.0405
gh_C	-0.0455	-0.0427	-0.0468	-0.0435	-0.0553	-0.0531
j_I	-0.0234	-0.0373	-0.0205	-0.0369	-0.0355	-0.0464
j_C	-0.0608	-0.0496	-0.0655	-0.0522	-0.0629	-0.0541
πh_I	-0.0551	-0.0585	-0.0586	-0.0625	-0.0584	-0.0611
πh_C	-0.0398	-0.0357	-0.0402	-0.0353	-0.0460	-0.0428
y_I	-0.0551	-0.0539	-0.1170	-0.1156	-0.1169	-0.1160
y_C	-0.0398	-0.0416	-0.0402	-0.0423	-0.1354	-0.1368
l_I	0.0000	0.0045	0.0000	0.0054	0.0000	0.0036
l_C	0.0000	-0.0059	0.0000	-0.0070	0.0000	-0.0046
r_{KI}	-0.0457	-0.0463	-0.0472	-0.0480	-0.0524	-0.0529
r_{KC}	-0.0457	-0.0463	-0.0472	-0.0480	-0.0524	-0.0529
k_I	-0.0094	-0.0076	-0.0113	-0.0092	-0.0061	-0.0046
k_C	0.0058	0.0047	0.0070	0.0057	0.0038	0.0029
r_{EI}	0.9528	0.9525	0.9509	0.9505	0.9320	0.9318
r_{EC}	0.9528	0.9525	0.9509	0.9505	0.9320	0.9318
e_I	-1.0079	-1.0064	-1.0095	-1.0077	-0.9904	-0.9893
e_C	-0.9926	-0.9940	-0.9911	-0.9928	-1.0089	-1.0101
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0551	-0.0539	-0.0586	-0.0572	-0.0584	-0.0575
πf_C	-0.0398	-0.0416	-0.0402	-0.0423	-0.0460	-0.0474
w_I	-0.0551	-0.0585	-0.0586	-0.0625	-0.0584	-0.0611
w_C	-0.0398	-0.0357	-0.0402	-0.0353	-0.0486	-0.0454
p	0.0648	0.0394	0.0778	0.0478	0.0474	0.0276
grh_I	0.0000	-0.0045	0.0000	-0.0054	0.0000	-0.0036
grf_I	-0.0159	-0.0261	-0.4670	-0.4790	-0.4814	-0.4893
grh_C	0.0000	0.0059	0.0000	0.0070	0.0000	0.0046
grf_C	-0.0970	-0.0865	-0.1048	-0.0923	-1.1764	-1.1682
gc_I	-0.0842	-0.0839	-0.0866	-0.0863	-0.1023	-0.1021
gc_C	-0.0842	-0.0839	-0.0866	-0.0863	-0.1023	-0.1021
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	-1.0000	-1.0000	-1.0000	-1.0000
t_C	0.0000	0.0000	0.0000	0.0000	-1.0000	-1.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 8, Full Simulation Results for An Increase in Transfer (Expenditure Maximizing)

Variable	Base Case		Base Case +Transfer to Interior		Base Case +Transfer to Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0282	-0.0385	-0.1502	-0.0768	-0.1024	-0.0579
v_C	-0.0588	-0.0489	0.0693	-0.0018	0.0308	-0.0124
c_{II}	-0.0435	-0.0495	0.0115	0.0545	0.0499	0.0759
c_{CI}	-0.0150	-0.0322	-0.2393	-0.1163	-0.1205	-0.0459
c_{IC}	-0.0798	-0.0611	0.3308	0.1969	0.2667	0.1855
c_{CC}	-0.0513	-0.0438	0.0799	0.0261	0.0963	0.0637
gh_I	-0.0316	-0.0343	-0.2175	-0.1978	-0.2987	-0.2867
gh_C	-0.0455	-0.0427	-0.3137	-0.3341	-0.4308	-0.4431
j_I	-0.0234	-0.0373	-0.1652	-0.0658	-0.0701	-0.0098
j_C	-0.0608	-0.0496	0.1640	0.0834	0.1534	0.1045
πh_I	-0.0551	-0.0585	0.1134	0.1375	0.1190	0.1337
πh_C	-0.0398	-0.0357	-0.0210	-0.0507	0.0278	0.0098
y_I	-0.0551	-0.0539	0.1134	0.1049	0.1190	0.1139
y_C	-0.0398	-0.0416	-0.0210	-0.0084	0.0278	0.0355
l_I	0.0000	0.0045	0.0000	-0.0326	0.0000	-0.0198
l_C	0.0000	-0.0059	0.0000	0.0424	0.0000	0.0257
r_{KI}	-0.0457	-0.0463	0.0305	0.0350	0.0627	0.0655
r_{KC}	-0.0457	-0.0463	0.0305	0.0350	0.0627	0.0655
k_I	-0.0094	-0.0076	0.0829	0.0699	0.0563	0.0484
k_C	0.0058	0.0047	-0.0514	-0.0434	-0.0349	-0.0300
r_{EI}	0.9528	0.9525	1.0440	1.0464	1.0719	1.0734
r_{EC}	0.9528	0.9525	1.0440	1.0464	1.0719	1.0734
e_I	-1.0079	-1.0064	-0.9306	-0.9415	-0.9529	-0.9595
e_C	-0.9926	-0.9940	-1.0649	-1.0548	-1.0441	-1.0379
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0551	-0.0539	0.1134	0.1049	0.1190	0.1139
πf_C	-0.0398	-0.0416	-0.0210	-0.0084	0.0278	0.0355
w_I	-0.0551	-0.0585	0.1134	0.1375	0.1190	0.1337
w_C	-0.0398	-0.0357	-0.0210	-0.0507	0.0278	0.0098
p	0.0648	0.0394	-0.5701	-0.3881	-0.3872	-0.2768
grh_I	0.0000	-0.0045	0.0000	0.0326	0.0000	0.0198
grf_I	-0.0159	-0.0261	1.0488	1.1219	1.1399	1.1843
grh_C	0.0000	0.0059	0.0000	-0.0424	0.0000	-0.0257
grf_C	-0.0970	-0.0865	0.2800	0.2043	0.7897	0.7438
gc_I	-0.0842	-0.0839	-0.5801	-0.5819	-0.7967	-0.7978
gc_C	-0.0842	-0.0839	-0.5801	-0.5819	-0.7967	-0.7978
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
tr_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000

Appendix5: Sensitivity Test 9, Full Simulation Results for a Cut in Tax (Welfare Maximizing)

Variable	Base Case		Base Case+ Tax Cut in Interior		Base Case +Tax Cut in Both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0144	-0.0379	-0.0087	-0.0378	-0.0324	-0.0470
v_C	-0.0699	-0.0490	-0.0776	-0.0516	-0.0669	-0.0539
c_{II}	-0.0390	-0.0478	-0.0392	-0.0501	-0.0477	-0.0532
c_{CI}	0.0055	-0.0299	0.0160	-0.0279	-0.0201	-0.0420
c_{IC}	-0.0956	-0.0594	-0.1095	-0.0645	-0.0829	-0.0604
c_{CC}	-0.0512	-0.0415	-0.0543	-0.0423	-0.0553	-0.0492
gh_I	-0.0168	-0.0388	-0.0116	-0.0390	-0.0339	-0.0476
gh_C	-0.0734	-0.0504	-0.0819	-0.0534	-0.0691	-0.0548
j_I	-0.0077	-0.0352	-0.0004	-0.0345	-0.0282	-0.0453
j_C	-0.0661	-0.0475	-0.0728	-0.0497	-0.0645	-0.0530
πh_I	-0.0571	-0.0571	-0.0616	-0.0616	-0.0587	-0.0587
πh_C	-0.0333	-0.0331	-0.0321	-0.0318	-0.0426	-0.0425
y_I	-0.0571	-0.0522	-0.1201	-0.1141	-0.1172	-0.1141
y_C	-0.0333	-0.0394	-0.0321	-0.0397	-0.1320	-0.1358
l_I	0.0000	0.0049	0.0000	0.0060	0.0000	0.0030
l_C	0.0000	-0.0063	0.0000	-0.0078	0.0000	-0.0039
r_{KI}	-0.0424	-0.0443	-0.0434	-0.0458	-0.0504	-0.0516
r_{KC}	-0.0424	-0.0443	-0.0434	-0.0458	-0.0504	-0.0516
k_I	-0.0147	-0.0079	-0.0182	-0.0098	-0.0083	-0.0041
k_C	0.0091	0.0049	0.0113	0.0061	0.0052	0.0025
r_{EI}	0.9552	0.9544	0.9536	0.9526	0.9336	0.9331
r_{EC}	0.9552	0.9544	0.9536	0.9526	0.9336	0.9331
e_I	-1.0123	-1.0066	-1.0153	-1.0082	-0.9923	-0.9888
e_C	-0.9885	-0.9938	-0.9857	-0.9923	-1.0072	-1.0105
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0571	-0.0522	-0.0616	-0.0556	-0.0587	-0.0557
πf_C	-0.0333	-0.0394	-0.0321	-0.0397	-0.0426	-0.0464
w_I	-0.0571	-0.0571	-0.0616	-0.0616	-0.0587	-0.0587
w_C	-0.0333	-0.0331	-0.0321	-0.0318	-0.0452	-0.0451
p	0.1011	0.0406	0.1254	0.0504	0.0629	0.0253
grh_I	0.0190	-0.0142	0.0278	-0.0134	0.0045	-0.0161
grf_I	-0.0207	-0.0140	-0.4767	-0.4685	-0.4791	-0.4750
grh_C	-0.0698	-0.0157	-0.0871	-0.0201	-0.0352	-0.0015
grf_C	-0.0314	-0.0600	-0.0242	-0.0597	-1.1417	-1.1595
gc_I	-0.0765	-0.0799	-0.0774	-0.0817	-0.0979	-0.1001
gc_C	-0.0765	-0.0799	-0.0774	-0.0817	-0.0979	-0.1001
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	-1.0000	-1.0000	-1.0000	-1.0000
t_C	0.0000	0.0000	0.0000	0.0000	-1.0000	-1.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix5: Sensitivity Test 9, Full Simulation Results for An Increase in Transfer(Welfare Maximizing)

Variable	Base Case		Base Case + Transfer to Interior		Base Case + Transfer to both Regions	
	SR	LR	SR	LR	SR	LR
v_I	-0.0144	-0.0379	-0.4099	-0.1215	-0.3230	-0.1031
v_C	-0.0699	-0.0490	0.2726	0.0157	0.1973	0.0014
c_{II}	-0.0390	-0.0478	-0.1073	0.0001	-0.0923	-0.0104
c_{CI}	0.0055	-0.0299	-0.6537	-0.2195	-0.5088	-0.1779
c_{IC}	-0.0956	-0.0594	0.5882	0.1425	0.4379	0.0982
c_{CC}	-0.0512	-0.0415	0.0418	-0.0772	0.0214	-0.0693
gh_I	-0.0168	-0.0388	-0.3805	-0.1097	-0.3005	-0.0941
gh_C	-0.0734	-0.0504	0.3150	0.0327	0.2296	0.0144
j_I	-0.0077	-0.0352	-0.4922	-0.1546	-0.3857	-0.1283
j_C	-0.0661	-0.0475	0.2249	-0.0035	0.1609	-0.0132
πh_I	-0.0571	-0.0571	0.1146	0.1144	0.0769	0.0767
πh_C	-0.0333	-0.0331	-0.1781	-0.1804	-0.1462	-0.1480
y_I	-0.0571	-0.0522	0.1146	0.0547	0.0769	0.0312
y_C	-0.0333	-0.0394	-0.1781	-0.1029	-0.1462	-0.0889
l_I	0.0000	0.0049	0.0000	-0.0597	0.0000	-0.0455
l_C	0.0000	-0.0063	0.0000	0.0775	0.0000	0.0591
r_{KI}	-0.0424	-0.0443	-0.0660	-0.0426	-0.0608	-0.0430
r_{KC}	-0.0424	-0.0443	-0.0660	-0.0426	-0.0608	-0.0430
k_I	-0.0147	-0.0079	0.1806	0.0973	0.1377	0.0741
k_C	0.0091	0.0049	-0.1120	-0.0603	-0.0854	-0.0460
r_{EI}	0.9552	0.9544	0.9634	0.9733	0.9616	0.9691
r_{EC}	0.9552	0.9544	0.9634	0.9733	0.9616	0.9691
e_I	-1.0123	-1.0066	-0.8488	-0.9186	-0.8848	-0.9380
e_C	-0.9885	-0.9938	-1.1415	-1.0762	-1.1078	-1.0581
e	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
πf_I	-0.0571	-0.0522	0.1146	0.0547	0.0769	0.0312
πf_C	-0.0333	-0.0394	-0.1781	-0.1029	-0.1462	-0.0889
w_I	-0.0571	-0.0571	0.1146	0.1144	0.0769	0.0767
w_C	-0.0333	-0.0331	-0.1781	-0.1804	-0.1462	-0.1480
p	0.1011	0.0406	-1.2420	-0.4993	-0.9467	-0.3806
grh_I	0.0190	-0.0142	-0.1346	0.2734	0.1513	0.4623
grf_I	-0.0207	-0.0140	0.8761	0.7946	0.6789	0.6169
grh_C	-0.0698	-0.0157	1.6164	0.9523	1.7407	1.2345
grf_C	-0.0314	-0.0600	-1.3405	-0.9894	-1.0527	-0.7851
gc_I	-0.0765	-0.0799	-0.7905	-0.7485	-1.0540	-1.0220
gc_C	-0.0765	-0.0799	-0.7905	-0.7485	-1.0540	-1.0220
d_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tr_I	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
tr_C	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000

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