

A Service of

ZBW

Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics

Groenewold, Nicolaas; Chen, Anping

Conference Paper An Increase in the Retirement Age in China: The Regional Economic Effects

55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Groenewold, Nicolaas; Chen, Anping (2015) : An Increase in the Retirement Age in China: The Regional Economic Effects, 55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at: https://hdl.handle.net/10419/124595

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



WWW.ECONSTOR.EU

An Increase in the Retirement Age in China: The Regional Economic Effects

Anping Chen, School of Economics, Jinan University, Guangzhou, China, <u>anping.chen@hotmail.com</u>

and

Nicolaas Groenewold,* Economics, University of Western Australia, Perth, Australia <u>nic.groenewold@uwa.edu.au</u>

*Corresponding author.

This research was partially funded by a National Natural Science Foundation of China Grant (No. 71173092) and the Program for New Century Excellent Talents in University, Ministry of Education of China (No. NCET-12-0681). We are grateful for the comments received at the Fourth International Workshop on Regional, Urban and Spatial Economics at Tsinghua University in June 2015, especially those of our discussant, Roberta Capello.

An Increase in the Retirement Age in China: The Regional Economic Effects

Abstract

China's pension system is in need of comprehensive reform in that it is fragmented in its coverage and significantly under-funded. One measure which has featured in various reform proposals and on which we focus in this paper is to increase the retirement age. Since demographics and industry structure differ considerably across the regions in China, it is likely that a change in retirement age will have significantly different effects across China's regions. Inter-regional disparities are already very substantial in China and it will be important to know whether changes in pension arrangements will widen or narrow these disparities. It is the object of the research reported in this paper to throw light on this question. To do this we construct a small two-region theoretical model having some Chinese characteristics. We linearise the model and solve it numerically using parameter values derived from Chinese data. We run four experiments, all involving an increase in the retirement age from 60 to 61. The simulations differ according the use made of the extra revenue generated by the policy. All four policies increase welfare and reduce the interregional welfare gap. However, the effects on other, more visible, measures of inter-regional gaps (such as income and output) are less clear and might generate resistance to the policy change, especially by the skilled who generally face reduced wages and income and have to work longer. (about 230 words)

Key words: China, pension system, retirement age, regional impacts JEL Classifications: R10, R23, R28, H70, H75

1. Introduction

The development of a socially adequate pension scheme which is financially sustainable is an important policy challenge in many countries, developed as well as developing. The difficulties many countries face reflect both inadequate pension systems inherited from the past as well as a rapidly changing demographic and social environment. In many countries pension reform is urgent, not only to correct existing weaknesses but also to prepare for future developments.

In all these aspects, China is no exception. By the beginning of the 21st century China had inherited a pension system which has been characterised as inadequate in many dimensions – it is fragmented, it is unfair, it is inefficient, it is substantially unfunded, it covers only a fraction of urban workers and almost no rural workers; see, e.g., Zheng (2007), Song (2009), Barr and Diamond (2010), Herd *et al.* (2010), Alonso *et al.* (2011), Dorfman *et al.* (2013), Cai and Cheng (2014) and Wang *et al.* (2014a,b).

Not only are there serious weaknesses in the pension system inherited from the past, but China faces structural economic changes, demographic pressures and social forces which will require thorough reform of its pension system if it is to provide suitable old-age security for the majority of its citizens over the coming decades.

Before the widespread reform of state-owned enterprises (SOEs) in the late 1980s and 1990s which followed the opening-up of China to the rest of the world in the early 1980s, the Chinese pension system was largely urban and firmly based on SOEs which paid for pensions out of their revenue and provided lifetime income security to employees. Rural workers had access to land which was considered to be the basis for the provision of income during old age. But with SOE restructuring, increasing non-SOE employment in the cities and largescale migration from the country to the cities, the old pension system was seen to be increasingly inadequate to meet even the most basic needs in old age for the majority of China's workers.

Significant reforms implemented in 1991, 1995 and 1997 and subsequent pilot programmes, moved towards greater coverage, improved funding and unification of different components of the existing schemes. By the first decade of the 21st century, however, many commentators such as Barr and Diamond (2010) argued that the weaknesses listed above were still very much present: coverage in rural areas was still low, a large proportion of urban workers outside the formal sector of SOEs, government and large, well-established private firms are not covered, portability is limited and pension liabilities are substantially unfunded – much of the ultimate responsibility for pensions rests with local and provincial governments.

In addition to the weaknesses of an inherited system, China faces continuing and rapid demographic and social change which will have a significant impact on the pension system. A major influence on the population age-structure has been the one-child policy (OCP), initially implemented in the early 1980s and of continuing effect, despite recent marginal relaxation of the rules. This has resulted in a reduction of the total fertility rate to significantly less than 2, the effect of which on population dynamics is exacerbated by the OCP-induced imbalance between births of boys and girls. Added to this are continuing improvements in life-expectancy. The implications for the support of the elderly can be seen in the dependency ratio (over-60s as a ratio of the working-age population) which is projected to rise from a level of 0.11 in 2010 to about 0.24 in 2030 (Herd *et al.*, 2010).

On the social side, there has been rapid urbanisation, fed substantially by internal migration. This has resulted in a rapid increase in the proportion of the rural population which is over 60 with a rural dependency ratio of 0.34 projected for 2030, with some projections suggesting a ratio greater than 0.60 by 2050 if current migration trends continue

(Herd *et al.*, 2010). At the same time, urbanisation has contributed to an erosion of traditional family support for the aged – the OCP has limited the likelihood of sons' caring for aged parents and inter-regional mobility has made this increasingly difficult. The result is that an increasing proportion of the aged population lives alone with little family support (see Herd *et al.*, 2010, Cai and Cheng, 2014, and Alonso *et al.*, 2011).

It is clear, then, that significant reform of China's system for supporting the aged is required and various proposals have been set out; see, e.g., Barr and Diamond (2008, 2010), Herd *et al.* (2010), Dorfman *at al.* (2013) and Cai and Cheng (2014). It is not the purpose of this paper to propose alternative reforms or to describe and evaluate the reforms which have been proposed. Rather, we take one aspect which has featured in many reforms, *viz.*, an increase in the age at which pensions become accessible (the "retirement age"), and examine its general economic effects within a multi-regional context. Li and Merette (2005), Zhang (2007), Cai (2008), Zeng (2011), Barr and Diamond (2008, 2010) and Dorfman *et al.* (2013) all discuss proposals regarding increases in the retirement age; of these Li and Merette (2005), Zeng (2011) and Dorfman *et al.* (2013) analyse possible effects; the first two focus on the pension system itself in the framework of a CGE model and the third on the labour market. A recent paper by Song *et al.* (2015) simulates the welfare effects of a range of pension reforms in China but does not include a change in the retirement age. None of these papers adds a regional dimension to their analysis.

We argue that it is important to examine the effects of various proposals not only on the operation of the pension system itself (although that will understandably be the main focus of many studies) but on the economy as a whole since effects of pension reform are likely to extend beyond the pension system itself. Moreover, we argue that, given the likely differential regional impact many policy proposals will have, it is also important to undertake such economic analysis in a multi-regional context; this is particularly so given the large inter-regional disparities in China and their importance in policy-making at the highest levels and the possibility that pension-reform proposals will exacerbate such disparities. Summary information to illustrate this point is provided in Table 1.¹

[Table 1 about here]

The table shows comparative data based on a standard division of China into two broad regions – the interior and the coast. At the beginning of the century per capita GDP in the coastal region was more than twice that in the interior. While this gap had narrowed considerably by 2013, it was still substantial at 67% and, moreover, masks considerable underlying diversity – for example, at the level of the individual provinces, the ratio of per capita GDP in the wealthiest province, Jiangsu, to that in the poorest, Guizhou, was more than 3 in 2013 Other differences between the regions are also striking – the interior has a relatively smaller urban sector, has more retired persons relative to the number of workers covered by pensions and people in the interior have a lower life-expectancy by about 4 years. It is clear, therefore, that inter-regional differences in China are large and it is likely that shocks to the retirement age will have different effects across the regions, making a regional dimension to the analysis of such shocks an important addition to our knowledge of the effects of pension reform.

We carry out our analysis within the framework of a small theoretical model which has various Chinese features. The model has two regions (coast and interior), two sectors (formal and informal), two types of labour (skilled and unskilled), two levels of government (central and regional) and captures some features of the Chinese tax-expenditure system.² We assume that skilled workers are employed only by the formal sector and the government

¹ For further exploration of regional disparities as well as a discussion of regional policy, see Chen and Groenewold (2013, 2014), Lin, Lin and Ho (2013), Rizov and Zhang (2014) and Herrerias and Monford (2015). ² While our structure drastically simplifies the structure of Chinese taxes, we would argue that it captures the salient features; see Zhang and Martinez-Vazquez (2003), Jin *et al.* (2005), Zhang (2006), Tochkov (2007), Shen *et al.* (2012), Jia *et al.* (2014) and Shen and Zou (2015) for information on aspects of the Chinese public finances.

and that only skilled workers have pension coverage. This reflects the implications of the references cited above that pension coverage of rural workers and unskilled workers in urban areas and even skilled workers in the urban informal sector is low and that pension coverage is concentrated amongst skilled government, SOE and corporate employees in the formal sector.³ In our model it is assumed that pensions are paid by regional governments; while this assumption does not completely reflect current practice, it is the case for government and SOE employees and, besides, many other parts of China's current pension scheme are still ultimately underwritten by local and provincial governments.⁴

While the model we set up is relatively simple, it is too complicated to solve analytically and we therefore linearise it and solve it numerically using parameter values derived from average Chinese data for the period 2008-2013. We describe in detail the results of four experiments, all of which involve a shock to the retirement ratio designed to mimic an increase in the retirement age from 60 to 61. In all cases the change generates more revenue for regional governments and the experiments differ according to the assumption made about the way in which this revenue is used: in the first two it is assumed that the regional governments use the extra net revenue resulting from the increase in retirement age for the provision of a government-provided consumption good, in the third case it is assumed that the government uses the revenue to finance extra infrastructure and in the fourth we assume that governments use the additional revenue to reduce pension premia (or increase pension payments).

All four simulations showed an increase in welfare for both household types, in both regions. Generally the welfare increase was greater for the unskilled households, with the exception being where the extra revenue was used for infrastructure. From a regional

³ For a similar distinction between informal and formal sectors in a pension context for China see Giles *at al.* (2011). For a more detailed discussion of the definition of formal and informal sectors with applications to China and India see Rada (2010).

⁴ See, e.g., Cai and Cheng (2014), Song (2009) and Zhang (2007).

perspective, the welfare improvement was always greater in the interior than in the coast, resulting in a narrowing of the welfare disparity between the two regions for all simulations. The effects of the policy on the other measure of disparities (income and output per capita) was less consistent across simulations; generally, in the short run at least, income and output disparities widened as a result of the retirement-age increase, the clear exception being where the additional revenue was returned to skilled households in the form of reduced pension premia or increased pension payments. In this case all three measures of inter-regional disparities showed a narrowing of the gap between the regions.

Thus, from a welfare perspective, a reduction in the retirement age seems an attractive policy. However, if more visible measures of the inter-regional gap such as income or per capita output are preferred, the verdict is less clear since then there are losers as well as winners and the losers can be expected to resist the introduction of the policy. The losers are particularly likely to be the skilled whose wages and incomes are eroded and, moreover, who have to work longer and who may, therefore, be expected to resist the implementation of the policy.

The remainder of the paper is structured as follows. In the next section we set out the model and also briefly discuss its linearisation and calibration. Section 3 is devoted to a specification of the simulations we carry out and section 4 contains a discussion of the results of these simulations. Conclusions are presented in section 5.

2. Model

The model has two regions, conventionally labelled interior and coast (i = I, C);⁵ two private sectors, formal and informal (j = F, N), each of which produces a homogeneous output; two types of households, skilled and unskilled (k = U, S); and two levels of government – a regional government in each of the two regions and a central government.⁶ We discuss each of these aspects of the model in turn, starting with the household sector.

Households. Households derive utility from the consumption of the two privately-produced goods as well as from a good supplied "free of charge" by governments. There are two types of households (skilled and unskilled) in each region. We assume a representative household of each type in each region with potentially different preferences modelled by a constant-elasticity-of-substitution (CES) utility function of the form:⁷

$$V_{ki} = \beta_{ki} (\gamma_{Nki} C_{Nki}^{-\rho_{ki}} + \gamma_{Fki} C_{Fki}^{-\rho_{ki}} + \gamma_{Gki} GH_i^{-\rho_{ki}})^{\frac{-1}{\rho_{ki}}}, \qquad i = I, C, \qquad k = U, S,$$
(1)

where V_{ki} = utility of the representative household of type k, region i,

- C_{Nki} = real private consumption of the informal-sector good per household of type k, region i,
- C_{Fki} = real private consumption of the formal-sector good per household of type *k*, region *i*,
- GH_i = real government-provided consumption good per household, region *i*,
- β_{ki} = the scale parameter for household of type k, region i,
- γ_{jki} = the share parameters, good *j*, household of type *k*, region *i*,

⁵ 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. Papers using this classification include Whalley and Zhang (2007), He *et al.* (2008), Fleisher *et al.* (2010) and Su and Jefferson (2012).

⁶ We use "private" in relation to the production sectors to mean non-general government and include SOEs and other government-owned producers in these sectors.

⁷ We include a list of variable definitions in Appendix 1.

 ρ_{ki} = the substitution elasticity parameter, household of type *k*, region *i* (the elasticity of substitution is $1/(1+\rho_{ki})$),

with:

$$\begin{array}{ll} \beta_{ki} > 0, & k = U, S, & i = I, C, \\ 0 < \gamma_{jki} < 1, & j = N, F, G, & k = U, S, & i = I, C \\ \gamma_{Nki} + \gamma_{Fki} + \gamma_{Gki} = 1, & k = U, S, & i = I, C, \\ \rho_{ki} > -1, & k = U, S, & i = I, C. \end{array}$$

Households maximise utility subject to a budget constraint. To formulate the household budget constraint we need to combine quantities of the two goods and we use unskilled labour as the *numeraire*, throughout. We introduce a value-added tax (VAT) into the model. Since there are no intermediate goods in the model, the VAT is equivalent to a tax on the value of final output, all of which is consumed and, since households are assumed to spend all their income, the VAT is also equivalent to an income tax. We therefore model households as "paying" the VAT which the central government collects at a given rate T_V so that the household budget constraint for household *k* in region *i* can be written as:

 $P_N C_{Nki} + P_F C_{Fki} = J_{ki}(1 - T_V),$ k = U, S, i = I, C,

where P_N and P_F are the prices of goods N and F in terms of unskilled labour and J_{ki} is household income in terms of unskilled labour for household type k, region *i*.

Utility maximisation subject to the household budget constraint gives the demand functions:⁸

$$C_{Nki} = \frac{J_{ki}(1 - T_{v})}{P_{N} + P_{F}(\frac{P_{N}}{P_{F}}\frac{\gamma_{Fki}}{\gamma_{Nki}})^{\frac{1}{1 + \rho_{ki}}}}, \qquad k = U, S, \qquad i = I, C,$$
(2a)

⁸ Note that there is no *i* subscript on P_N or P_F . This reflects the assumption, to be made explicitly below, that both goods are freely traded between regions so that, in the absence of transportation costs, there will be a single price, nationwide.

$$C_{Fki} = \frac{J_{ki}(1 - T_{v})}{P_{F} + P_{N}(\frac{P_{F}}{P_{N}}\frac{\gamma_{Nki}}{\gamma_{Fki}})^{\frac{1}{\rho_{ki}+1}}}, \qquad k = U, S, \qquad i = I, C.$$
(2b)

Households receive income from wages, profits and pensions. Firms in the formal sector distribute profits (in equal-per-capita amounts) to skilled households in their own region while firms in the informal sector distribute profits (in equal-per-capita amounts) to unskilled households in their own region.

To reflect the partial pension coverage in China, as described in section 1, we assume that only skilled labour is covered by a pension plan and therefore retired skilled workers in region *i* receive a pension, W_{Ri} , and employed skilled workers pay a pension premium, R_i , to the government. It is assumed that in region *i* a fixed proportion, r_i , of skilled workers have retired, this proportion being the outcome of government policy and the population age structure, both of which we assume to be exogenous. Unskilled households do not retire, do not receive a pension and are not required to pay a pension premium. The income for the representative unskilled household can therefore be written as:

$$J_{Ui} = 1 + \Pi H_{Ni}, \qquad i = I, C, \qquad (3a)$$

where the first term on the right-hand side is the wage (the unskilled wage is *numeraire*) and ΠH_{Ni} denotes the representative unskilled household's share of profits from the informal sector. Employed skilled households receive a wage, W_{Si} , an equal share of formal-sector profits, ΠH_{Fi} , retired skilled workers receive a pension and all employed skilled workers pay a pension premium. We can therefore write income for the representative skilled household as:

$$J_{Si} = (1 - r_i)(W_{Si} - R_i) + r_i W_{Ri} + \Pi H_{Fi}, \qquad i = I, C.$$
(3b)

Households may migrate between sectors and between regions. In China, interregional migration has traditionally been subject to restrictions based on the household registration, or *hukou*, system which we model as imposing a cost on migration.⁹ We model the system as one in which no restrictions are imposed on inter-sectoral migration or on inter-regional migration by unskilled labour but costly restrictions are imposed on the inter-regional migration of skilled households. There is no inter-sectoral migration by skilled workers since they are employed only in the formal sector. Therefore, there is a single, nationwide unskilled wage. Inter-regional migration by skilled labour occurs to equalise the skilled wage across regions subject to migration costs and it does this only in the long run.¹⁰ In the short run regional skilled labour supplies are assumed exogenous. To simplify the migration equilibrium condition, we assume that inter-regional migration flows are dominated by those from the poor to the rich region. This assumption avoids the discontinuities which result from two-way costly migration; see Woodland and Yashida (2006) for an approach similar to ours but applied to immigration from poor to rich countries. Thus in long-run equilibrium the skilled wage in the coast (the richer region) will exceed the skilled wage in the interior by the *hukou* cost which we assume to be proportional to the wage:

$$W_{SC} = W_{SI}(1+\mu), \tag{4}$$

where μ is the *hukou* cost parameter.

Firms. We assume that the number of firms in each sector (formal and informal) and in each region is fixed and, without loss of generality, we set this number equal to 1 in each case.

The firm in the informal sector produces output using land (in fixed supply), unskilled labour and a public infrastructure good provided by the regional government. The firm in the

⁹ See Cheng and Selden (1994) for a general description and history of the *hukou* system. and Bao *et al.* (2011) for a more recent discussion and modelling considerations.

¹⁰ Note that, for simplicity, we ignore the fact that skilled households have both working and retired members, so that inter-regional differentials in the pension ought also to be taken into account in the migration decision. This would shift the tax base in response to changes in pensions; see Novy-Marx and Rauh (2014) for evidence of this effect.

formal sector uses both skilled and unskilled labour as well as capital (in fixed supply) and an infrastructure good provided by the government in its region.¹¹ Both sectors use Cobb-Douglas constant-returns-to-scale production technology:

$$\begin{split} Y_{Ni} &= B_{Ni} (LAND)^{(1-\alpha_{NUi}-\alpha_{NGi})} \left(L_{NUi} \right)^{\alpha_{NUi}} (GRF_{Ni})^{\alpha_{NGi}}, \qquad 0 < \alpha_{NUi}, \alpha_{NGi}, (1-\alpha_{NUi}-\alpha_{NGi}) < 1, \\ Y_{Fi} &= B_{Fi} (CAPITAL)^{(1-\alpha_{FUi}-\alpha_{FSi}-\alpha_{FGi})} L_{FUi}^{\alpha_{FUi}} L_{FSi}^{\alpha_{FSi}} (GRF_{Fi})^{\alpha_{FGi}}, \\ &\qquad 0 < \alpha_{FUi}, \alpha_{FSi}, \alpha_{FGi}, (1-\alpha_{FUi}-\alpha_{FSi}-\alpha_{FGi}) < 1, \end{split}$$

where B_{Ni} is total factor productivity (TFP), L_{NUi} is total (unskilled) employment in the informal sector and GRF_{Ni} represents regional government expenditure on infrastructure which benefits firms in the informal sector, all in region *i*. Similarly, B_{Fi} is TFP in the formal sector, L_{FUi} and L_{FSi} are employment of unskilled and skilled workers in this sector and GRF_{Fi} is infrastructure provided by region *i*'s government to firms in the formal sector in the region. Since we assume both land and capital to be immobile factors in fixed supply, we can simplify and write:

$$D_{Ni} = B_{Ni} (LAND)^{(1-\alpha_{NUi}-\alpha_{NGi})},$$

and

$$D_{\rm Fi} = B_{Fi} (CAPITAL)^{(1-\alpha_{FUi}-\alpha_{FSi}-\alpha_{FGi})}$$

so that the production functions can be written as:

$$Y_{Ni} = D_{Ni} L_{NUi}^{\alpha_{NUi}} (GRF_{Ni})^{\alpha_{NGi}}, \qquad 0 < \alpha_{NUi}, \alpha_{NGi}, (1 - \alpha_{NUi} - \alpha_{NGi}) < 1, \quad i = I, C, \text{ and} \quad (5a)$$

$$Y_{Fi} = D_{Fi} L_{FSi}^{\alpha_{FSi}} L_{FUi}^{\alpha_{FUi}} (GRF_{Fi})^{\alpha_{FGi}}, \qquad 0 < \alpha_{FSi}, \alpha_{FUi}, \alpha_{FGi}, (1 - \alpha_{FSi} - \alpha_{FUi} - \alpha_{FGi}) < 1 \qquad (5b)$$

$$i = I, C.$$

Consider now firms' behaviour. Profits (in terms of units of unskilled labour) are defined as:

¹¹ It is clearly more plausible to assume inter-regional immobility of land than immobility of capital. Nevertheless, it is possible to argue that capital moves more slowly than labour and to restrict our analysis to the length of time in which labour, but not capital, can move. Besides, experimentation with an earlier version of this model suggests that introducing capital mobility considerably complicates the interpretation of results of many shocks without changing their overall thrust.

$$\Pi_{Ni} = (1 - T_{Ni})P_N Y_{Ni} - L_{Nui}, \qquad i = I, C, \qquad (6a)$$

$$\Pi_{Fi} = (1 - T_{Fi})P_F Y_{Fi} - L_{FUi} - W_{Si} L_{FSi}, \qquad i = I, C,$$
(6b)

where T_{Ni} is the tax on informal-sector output and T_{Fi} is the tax levied on the value of output of the formal sector and W_{Si} is the skilled wage relative to the unskilled wage, all in region *i*. We assume that each firm takes the wage, the tax rate and the quantity of infrastructure as given. Hence the only choice variable in each case is the level of employment – unskilled in the informal sector and both skilled and unskilled in the formal sector – and this choice will also determine output via the production function. We follow convention and assume that firms in both sectors choose employment to maximise profits. The profit-maximising conditions will result in the usual marginal productivity conditions. For the formal sector

$$\alpha_{FSi}(1-T_{Fi})P_F Y_{Fi} = W_{Si}L_{FSi}, \quad i = I, C,$$
(7a)

$$\alpha_{FUi}(1-T_{Fi})P_FY_{Fi} = L_{FUi}, \qquad i = I, C,$$
(7b)

and for the informal sector:

$$\alpha_{NUi}(1-T_{Ni})P_N Y_{Ni} = L_{NUi}, \qquad i = I, C.$$
(7c)

On the labour supply side, each unskilled household provides one unit of labour inelastically and each skilled household provides $(1 - r_i)$ units of labour inelastically. Hence population, labour force, labour supply, employment and the number of households are all equal for the unskilled population but for the skilled there is a distinction between population and households (which are equal), on the one hand, and employment and labour force (which are equal), on the other. We use Q_U, Q_S and Q to denote the number of unskilled, skilled and total households respectively.

Governments. There are two levels of government in the model: central and regional. Following our description of the pension system in China in Section 1, we assume that, while the central government determines the parameters of the pension system, pensions are administered at the regional level by provincial and local governments. In addition, given the evidence that in many cases local and provincial governments are financially responsible, as a last resort, for pension payments, we simplify the structure of the model and assume that pension premium income and pension payments are part of the regional governments' budgets.

The central government levies a VAT at a uniform rate across the country and shares the revenue with the regional governments, returning a share $(1 - \theta)$ of the revenue raised in each region. The central government uses its tax revenue to provide a government consumption good to the residents of each region in amounts which are the same per capita in each region but may differ across the regions. It produces this good using only skilled labour which it hires in the market in the region in which the good is provided. Production technology is linear:

$$Q_i G C_i = L_{GCSi}, \qquad i = I, C, \tag{8}$$

where L_{GCSi} is the amount of skilled labour hired by the central government in region *i* and Q_i is population of region *i*. The government budget constraint in terms of units of unskilled labour is:

$$Q_I P_{GCI} GC_I + Q_C P_{GCC} GC_C = \theta T_V [(Q_{SI} J_{SI} + Q_{UI} J_{UI}) + (Q_{SC} J_{SC} + Q_{UC} J_{UC})].$$
(9)

where P_{GCi} is the price of central government output in region *i*, Q_{Si} is the population of skilled worker households in region *i* and Q_{Ui} is the population of unskilled worker households in region *i*.

Regional governments levy a tax on the productive activities of both sectors in their region at rates T_N and T_F . They also receive a share, $(1 - \theta)$, of the VAT levied by the central government as well as pension premium income from skilled workers in the formal sector in their region. Each regional government provides a consumption good to households within its region in equal per capita amounts, as well as providing infrastructure (non-rival in use) to

firms in both sectors. Regional governments also pay pensions to retired skilled workers. The regional governments' budget constraints therefore have the form:

$$Q_{i}P_{GRi}GRH_{i} + P_{GRi}(GRF_{Ni} + GRF_{Fi}) + r_{i}Q_{Si}W_{Ri} = (1-\theta)T_{V}(Q_{Si}J_{Si} + Q_{Ui}J_{Ui}) + T_{Ni}P_{N}Y_{Ni} + T_{Fi}P_{F}Y_{Fi} + (1-r_{i})Q_{Si}R_{i}, \quad i=I,C,$$
(10)

where P_{GRi} is the price of the regional government's output in region *i*, GRH_i is the amount per capita of the government good provided by region *i*'s government to households in its region and GRF_{ji} is the amount of the infrastructure good provided to the firms in sector *j*, region *i*. The components on the right-hand side of (10) are the regional government's share of the VAT, tax revenue from the output tax on the two sectors and income from the pension premium paid by skilled workers in its region.

It is assumed that regional governments have the same production technology as the central government and produce an identical good which can be provided either as a consumption good to households or to firms as infrastructure. Thus

$$Q_i GRH_i + GRF_{Ni} + GRF_{Fi} = L_{GRSi}, \qquad i = I, C, \qquad (11)$$

where L_{GRSi} is the amount of skilled labour employed by the regional government in region *i*.

The simple government production function implies that the relative price of the government good in region i, P_{GCi} , and P_{GRi} , is simply the real wage of skilled labour in region i, W_{Si} :

$$P_{GCi} = P_{GRi} = W_{Si}, \qquad i = I, C. \tag{12}$$

Closure and definitions. It remains to define a number of important aggregate variables and set out market-clearing conditions to complete the specification of the model.

First, the aggregate counterparts of a number of regional variables are defined. We begin with output and define both regional output and national output which are given, in terms of units of unskilled labour, by:

$$Y_i = P_N Y_{Ni} + P_F Y_{Fi}, \qquad i = I, C, \qquad (13a)$$

$$Y = Y_I + Y_C. \tag{13b}$$

Similarly for income (per capita) at the regional and national levels. Since income is already defined in terms of units of unskilled labour we just weight regional per capita incomes by populations and add:

$$J_i = (Q_{Ui}/Q_i)J_{Ui} + (Q_{Si}/Q_i)J_{Si}, \qquad i = I, C,$$
(14a)

$$J = (Q_I/Q)J_I + (Q_C/Q)J_C.$$
 (14b)

The appropriate procedure for welfare is less straightforward because of the problem of interpersonal comparison of utilities. We decide to treat all individuals equally and simply measure regional and national welfare as the population-weighted average of the utilities of the different households in each case:

$$V_{i} = (Q_{Ui}/Q_{i}) V_{Ui} + (Q_{Si}/Q_{i}) V_{Si}, \qquad i = I, C, \qquad (15a)$$

$$V = (Q_I/Q)V_I + (Q_C/Q) V_C.$$
 (15b)

Next, we introduce a number of definitions and market clearing conditions.

 GH_i , the amount of the government good per capita received by households in region *i* from both sources (regional and national governments), is the sum of its components since both levels of government produce an identical good:

$$GH_i = GRH_i + GC_i, \qquad i = I, C.$$
(16)

Market-clearing conditions are imposed on goods and labour markets. It is assumed that the output of each sector is homogeneous across regions and trades freely between regions making market-clearing a national condition. All private production is consumed so that goods-markets clearing in each sector implies that national output is equal to national consumption:

$$Y_{NI} + Y_{NC} = Q_{UI}C_{NUI} + Q_{SI}C_{NSI} + Q_{UC}C_{NUC} + Q_{SC}C_{NSC},$$
(17a)
and

$$Y_{FI} + Y_{FC} = Q_{UI}C_{FUI} + Q_{SI}C_{FSI} + Q_{UC}C_{FUC} + Q_{SC}C_{FSC}.$$

$$(17b)$$

Market-clearing is also imposed on the labour markets:

$$L_{NUi} + L_{FUi} = L_{Ui}, \qquad i = I, C, \qquad (18a)$$

$$L_{FSi} + L_{GCSi} + L_{GRSi} = L_{Si}.$$
 $i = I, C,$ (18b)

where L_{Si} and L_{Ui} are employment of skilled and unskilled workers respectively, in region *i*.

The relationship between labour supply and population is straightforward. The number of unskilled households equals the unskilled labour force and the number of skilled households equals the skilled labour force plus retired skilled workers:

$$L_{Ui} = Q_{Ui}, \qquad \qquad i = I, C, \tag{19a}$$

$$L_{Si} = (1 - r_i)Q_{Si}, \qquad i = I, C.$$
 (19b)

Regional and national populations are defined as:

$$Q_U = Q_{UI} + Q_{UC},\tag{19c}$$

$$Q_S = Q_{SI} + Q_{SC}, \tag{19d}$$

$$Q_i = Q_{Ui} + Q_{Si}, \qquad i = I, C, \tag{19e}$$

$$Q = Q_S + Q_U. \tag{19f}$$

Firms are assumed to distribute all their profits to households in their own region in equal per capita amounts.

$$\Pi_{Ni} = Q_{Ui}\Pi H_{Ni}, \qquad i = I, C, \qquad (20a)$$

$$\Pi_{Fi} = Q_{Si}\Pi H_{Fi}, \qquad i = I, C.$$
(20b)

This completes the specification of the model. To summarise, the short-run version of the model consists of 71 equations, (1) to (3) and (5) to (20) in 70 endogenous variables: V_{ki} , C_{jki} , GH_i , P_j , J_{ki} , ΠH_{ki} , Y_{ji} , L_{jUi} , L_{FSi} , Π_{ji} , W_{Si} , GC_i , $(GRH_i \text{ or } GRF_{ji} \text{ or } R_i)$, Q_i , L_{GCSi} , L_{GRSi} , P_{GCi} , P_{GRi} , Y, Y_i , J, J_i , V, V_i , L_{Ui} , L_{Si} , Q_{Ui} , Q_S , $Q_{.}$.¹² One of the equations is redundant,

¹² For all simulations set out in the next section it will be assumed that while the GC_i variables are endogenous, they will be constrained so that the proportional changes are equal across the regions. Further, which of the variables (GRH_i or GRF_{ji} or R_i) is endogenous depends on the simulation; if the GRF_{ji} are endogenous we will impose additional restrictions that the changes are equal across the sectors but may differ across regions.

however, since the household and government budget constraints, definitions and one of the product-market clearing conditions imply the remaining product-market clearing condition; we drop one of the product-market clearing conditions in the simulations which follow.

Short-run and long-run versions of the model. The model set out above is the short-run version of the model. It is defined by the assumption that skilled labour is not interregionally mobile which is reflected by the fact that the regional populations of skilled households are exogenous. We relax this assumption in the long run by making these populations endogenous (although subject to an exogenous national population of skilled households) and by adding the migration equilibrium equation (4). In this approach to the short-run/long-run distinction we follow Krugman (1991) and define the short run as the length of time before inter-regional migration adjusts to the changes in the wage differential. The distinction is based on the idea that migration is slow to respond fully to changes in economic incentives. Thus, for example, Pissarides and McMaster (1990) estimate that it takes as long as 20 years for reasonably complete adjustment of migration to labour-market shocks.

Linearising and calibrating the model. The model as it stands is too complicated to solve analytically so that we linearise it in terms of proportional changes for which we use a process of log differentiation. This converts the model from one which is non-linear in the levels to one which is linear in the proportional rates of change of the variables. The resulting linearised versions of equations (1)-(20) are given in Appendix 2.

Having linearised the model in terms of proportional changes, we can solve the model for any one of the (changes in the) endogenous variables in terms of (the changes in) the exogenous variables. However, given the number of endogenous variables, this is unlikely to lead to any interpretable results and we proceed to solve the model numerically, using data for China's regions (reported in Table 2) to calibrate the key parameters of the model, detailed discussion of which we relegate to Appendix 3.

[Table 2 about here]

3. Simulations

In the next section we report the results of four simulations. All reflect the effects of an increase in the retirement age from 60 to 61 but differ in the way in which the regional government budget is assumed to adjust.¹³ In the first, the regional government is assumed to adjust its provision of the government consumption good (*GRH_i*). It may seem unlikely that a government would propose a policy of increasing the retirement age in order to generate revenue to increase government consumption but what we have in mind here is that the government was funding the unfunded part of a pension scheme with money it would otherwise have spent on consumption goods. Removing this drain on the government's budget allows it to spend more on the provision of the government consumption good.

We find significant differences in the regional effects of the policy in simulation 1 and ask whether this is because of initial shocks which are unequal across the regions or because the regions' different structures translate similar shocks into different ultimate effects (differences in the propagation mechanism). We assess this in simulation 2 by re-running simulation 1 but with shocks to the retirement ratio which are equal across the regions.

In the third simulation we assume that the regional government adjusts infrastructure expenditure (GRF_{ji}) to balance its budget. Again, it is unlikely that a regional government would finance infrastructure expenditure by raising the retirement age but we imagine that

¹³ We note that there have also been proposals to (eventually) raise the retirement age to 65 and we have re-run our simulations under this assumption. While the shocks in this case are not simply a scaling up of the shocks for the 60 to 61 case (since there are different effects in the two regions), the shocks to r_1 and r_c are a little over 4 times the shocks for the 60 to 61 case. The simulation results reflect this and by and large are about 4 to 4.5 times those for the base case. We report these in Appendix 5.

previously the regional government was topping up pensions with funds which it would otherwise have spent on infrastructure so that the pension reform allows it to reallocate money to infrastructure.¹⁴

In the fourth simulation we assume that the revenue generated by the increase in retirement age is used to reduce the pension premium (R_i) . In our model, this has the same effects as an increase in the pension (W_{Ri}) .

The shock in each case is to the proportion of the skilled population which is retired, r_i . The size of the shock is chosen so as to mimic the effect of an increase in retirement age from 60 to 61.¹⁵ While the reduction in the retirement age is the same for the two regions, the actual proportional change in r_i differs across regions because r_i itself, life expectancy and, so, the proportion of retirees who are 60, all differ across the regions. The effect of these differences is that the proportional shock to r_i is -0.1170 for the coast and -0.1481 for the interior region. The reason for the larger shock to the interior region is that it has a higher proportion of the skilled population retired but a lower life-expectancy so that, in the interior, 60-year-olds form a greater proportion of the retired skilled population.¹⁶ We apply the same shock to r_i in all but the second simulation which, as explained above, is the same as the first except that we force the changes in r_i to be the same across the regions.

4. Results

In this section we report the results of four simulations of the model: simulation 1 with GRH_i endogenous, simulation 2 also with GRH_i endogenous but equal shocks to r_I and r_C , simulation 3 with GRF_{ji} endogenous and simulation 4 with R_i endogenous.

¹⁴ Since there are two infrastructure variables in each regional government budget constraint (one provided to formal-sector firms) but only one degree of freedom, we constrain the proportional changes in the two variables within the region to be the same.

¹⁵ Note that we assume that all skilled workers who are eligible to retire do so and that this continues to be the case after the policy change; evidence that this is so is provided in a recent paper by Behaghel and Blau, (2012). ¹⁶ Details of the computation of shock sizes are provided in Appendix 3.

4.1 Simulation 1: GRH_i endogenous in the regional governments' budget constraints

The shock is a fall in r_i , which, as explained above, is set to -0.1170 and -0.1481 for the coast and interior respectively. These are proportional changes in r_i and the results are multiplied by 100 so that they may be interpreted as percentages. Selected results are reported in Table 3 with the full set reported in Appendix 4.

[Table 3 about here]

We begin with the short-run effects. The "initial" effect of the increase in the retirement age is on the supply of skilled labour which increases by 4.96% nationally, with both regions' labour supply going up: by 6.18% and 3.63% for the interior and the coast respectively.¹⁷ The larger effect for the interior reflects both the larger shock and the fact that a higher proportion of the skilled labour force is retired.¹⁸

Since labour markets clear and supply is inelastic, the increase in skilled labour supply must be employed – either by the formal sector or by government or both. The increase in employment requires a fall in the relative wage for skilled workers and it does so by more in the interior where the expansion of the labour supply is larger.

The increases in employment by the private firms are of a similar order of magnitude across the regions, although larger for the interior than for the coast (2.36% and 2.06% respectively) reflecting the different shock sizes and consequent wage falls.

Both levels of government increase their employment of skilled labour. This is made possible by the lower cost of skilled labour (the only factor used in government production)

¹⁷ We abstract from possible heterogeneity in the skilled labour force which might be particularly important in some cases since the extra workers will all be 60-year-olds whose skills may differ materially from those of the average skilled worker; for interesting recent evidence of this effect in education see Fitzpatrick and Lovenheim (2014).

¹⁸ From the linearised equation for the supply of skilled labour, (19') and the assumption that in the short run the skilled population is exogenous in each region, a unit fall in r_i in each region implies that l_{Si} is equal to $r_i/(1-r_i)$ which is increasing in r_i .

so that with the same resources governments can increase their supply of the government good. In addition, the regional government's budgetary position improves both because of the smaller number of pensions to be paid and because of the greater number of skilled workers who pay the pension premium. It is not surprising, therefore, that the increase in the regional governments' supply of the government good is considerably greater than that of the central government.

Another feature of the government employment effect is that it is much larger in the interior than it is in the coast. This reflects the difference in size of the initial shocks as explained previously so that the mechanism discussed above is stronger in the interior than it is in the coast.

Output rises in both sectors although by considerably more in the formal sector since only the formal sector employs skilled labour. The increase in output of the informal sector is caused by the release of labour from the formal sector where firms substitute skilled for unskilled labour as the relative skilled wage falls. The effects for both sectors are larger in the interior.

Incomes change under two influences – wages and profits. Unskilled incomes rise and skilled incomes fall. The rise in unskilled income reflects increasing informal-sector profits driven by a small increase in the price of informal-sector output. The effect is larger in the interior. The influences on skilled income are more complicated. First, the fall in the retirement proportion increases wage income net of pension payments and premia; second, wage income falls significantly and, third, formal sector profits also fall. The fall in skilled household incomes is roughly equivalent in both regions which reflects the larger wage fall in the interior but a larger profit fall in the coast. Why do formal-sector profits change? The wage bill falls (the skilled wage falls by more than the increase in skilled employment and unskilled employment falls) and output increases. But these two positive effects are more

than offset by the fall in the relative price of formal sector output, resulting in an overall fall in profits. This feeds through into profit distribution to skilled households and therefore to their incomes.

The changes in incomes directly affect consumption. For unskilled households consumption of both goods rises in both regions, reflecting the increase in incomes in both regions. The relative regional magnitude is the same for each of the goods and reflects that of incomes, with a larger rise in the coast. Consumption of the formal good rises more than that of the informal good, reflecting a relative price change in favour of the formal good. For skilled households consumption changes are smaller than for unskilled households and signs are mixed. Their consumption of formal goods rises in both regions while consumption of informal goods falls in both regions. This reflects the combined effects of income falls for skilled households and relative price movements against the informal-sector good.

Welfare depends on both private consumption and consumption of the government good. Consider government consumption, *GH*, first. *GH* increases by a large proportion in both regions but more in the interior than in the coast: 14.28% and 10.46% in the interior and the coast respectively. Since central government expenditure is constrained to increase in the same proportion in the two regions (and is small), the regional difference in the change in *GH* largely reflects changes in the consumption good provided by the regional governments, *GRH*, which are 32.81% and 16.11% in the interior and the coast respectively. This clearly reflects the greater increase in skilled employment in the production of the government good in the interior and the consequent greater fall in the relative skilled wage in that region.

Turning to the effects of these changes on welfare, we see that welfare goes up for each type of household in both regions but it goes up by more for unskilled households than for skilled households and by more in the interior for both household types. The difference between skilled and unskilled household welfare is not surprising since the increases in

consumption are bigger for the unskilled households and all households receive the same increase in government consumption. The different regional effects reflect a balance between the influences of private and public consumption. For unskilled households, private consumption of both goods increases more in the coast than in the interior but the effect of this on welfare is more than offset by the larger increase in government consumption in the interior, so that the overall welfare increase is greater in the interior. For the skilled households the effects of private and public consumption on welfare both work in the same direction – both types of consumption increase by more (or fall by less) in the interior, making for an unambiguously greater increase in welfare for the skilled households in the interior than for their coastal counterparts.

Finally, we consider the implications for inter-regional disparities. In examining these we return to the main question of this paper: are regional disparities widened or narrowed by the regional repercussions of a national increase in the retirement age?

Disparities can be measured in a number of ways and we use three measures: per capita output, per capita income and welfare. They are reported in the last three rows of Table 3 where disparities are measured so that a positive change represent a widening of the gap between the coast and the interior.

Table 3 shows that the gaps in both output per capita and income widen as a result of the increase in the retirement age. The underlying effects are mixed, however: while output per capita of both formal- and informal-sector output rises by more in the interior, the income of unskilled households rises by more in the coast but that of skilled households falls by less in the interior. The welfare measure shows an unambiguous result: it rises by more in the interior for both types of households so that the disparity in welfare narrows. The contrast between the implications for the welfare measure of disparities and the more common income

and output measures is due largely to the fact that the latter two omit the effects of changes in government expenditure which, as we saw above, greatly favour the interior.

To summarise the short-run effects, the increase in retirement age "initially" increases skilled labour supply and employment, by more in the interior than in the coast. This reduces the skilled wage, by more in the interior than in the coast. Output of each good increases in each region but formal-sector output increases by more and about the same in the two regions. The price of the informal sector's output rises and the price of the formal sector's output falls. With the change in the relative wage favouring unskilled labour, the income of skilled households falls but that of unskilled households rises. Welfare increases in both regions for both household types but by more for unskilled than skilled and by more in the interior than in the coast. Generally the effects of the increase in the retirement age differ more between the household types than between regions. Increasing the retirement age would seem to be a good policy, therefore, since all groups gain in welfare terms. In addition, the inter-regional welfare disparity is reduced. But the analysis ignores the disutility of working longer for those who would otherwise retire (or the utility of retirement for those who have to work an extra year).

We now briefly turn to the long-run effects. Recall that the distinction between short and long runs is that in the long run skilled households can migrate and they do this in response to wage differentials across the regions. Skilled wages fall in both regions in the short run but the fall is larger in the interior so that we expect migration of skilled workers from the interior to the coast, which in fact happens. This is slightly offset by a reversal of the short-run migration of unskilled workers from the coast to the interior. Skilled households in the coast now suffer a greater drop in income than they did in the short run but the reverse is true for interior skilled workers whose income fall is moderated by the migration outflow. This greater fall in coastal skilled incomes, leads to a substantial worsening of their welfare

although it is still better than in the initial situation. Inter-regional welfare disparities are therefore further narrowed as are disparities in per capita output and household income. In general, migration narrows the inter-regional gaps between corresponding variables compared to the short run and compared to the original equilibrium.

4.2 Simulation 2: GRH_i endogenous in the regional governments' budget constraints; equal shocks

The effects of the increase in retirement age reported in simulation 1 showed generally greater effects in the interior region. The question arises as to whether this simply reflects the larger shock to the retirement ratio in the interior or whether it also reflects differences in the propagation mechanism. We test this by re-running simulation 1 with equal shocks to r_I and r_C . The results are reported as simulation 2 in Table 3.¹⁹

We focus on the main variables and, in particular, on the inter-regional comparisons. As before, the increase in the skilled labour supply in the interior exceeds that in the coast, despite the equal changes in the retirement ratio across the regions. This reflects the fact that in the data base the retirement ratio is higher in the interior so that an equi-proportionate increase in the ratio has a larger labour supply effect in the interior. The skilled wage falls in each region to ensure the employment of the extra skilled workers, but in this case by more in the coast, rather than in the interior, showing that firms in the coast region are more sensitive to the change in labour supply in the sense that they require a larger wage reduction to employ the extra skilled workers. In the new simulation, output in the formal sector rises by more in the coast, in contrast to the previous case, reflecting the shift in the shock size in favour of the coast. Skilled household income falls in both regions, but the relative regional magnitudes are reversed – the fall is now bigger in the interior. Unskilled household incomes

¹⁹ We estimate the size of the equal shock by assuming a population structure between 60 and life expectancy which is the average of the two regions.

rise by a small amount in proportions similar to the previous simulation. Finally, utility rises for both household types in both regions and the relative magnitudes do not change: for both households, the utility gain in the interior is larger, although the regional differences have narrowed. The larger increases in the interior reflect the continuation of the larger increase in government consumption in the interior. As a result, the inter-regional gap in welfare still narrows but by a smaller amount. Moreover, the output and income gaps widen, as before, and by more than in simulation 1.

We found that, in simulation 1, many variables in the interior reacted more strongly to the increase in the retirement age than did their coastal counterparts and asked whether this was due to the larger shock in the interior or the propagation mechanism. We addressed this in the current simulation by equalising the shocks and found that, indeed, the size of the shock has an important bearing on the regionally-differentiated effects: the relative regional magnitudes are reversed for the skilled wage, output in the formal sector and skilledhousehold income but not for utility. The inter-regional gaps all changed in the same direction in the current simulation as in the previous simulation although the improvement in the welfare gap was smaller and the deterioration in the output and income gaps was larger.

4.3 Simulation 3: GRF_i endogenous in the regional governments' budget constraints

In the previous two simulations we assumed that the extra revenue generated for the regional governments by the rise in the retirement age was used to increase the provision of the government consumption good. In contrast, in the current simulation we assume that the regional governments use the additional revenue to fund extra infrastructure expenditure.

The results are shown in the third pair of columns in Table 3.²⁰ We focus on a comparison to simulation 1.

The initial shocks to the retirement ratios and the consequent changes in the supplies of skilled labour are as before. The skilled wage again falls in both regions but by considerably less than in simulation 1. This reflects the increase in the marginal product of skilled labour caused by the increase in infrastructure provision. Moreover, the increase in infrastructure is larger in the interior because of the greater increase in interior government revenue. Thus the fall in the wage in the interior is moderated by more than in the coast.

The output effects are very different to those in simulation 1 because of the effect on both formal- and informal-sector outputs of the boost to infrastructure. The output effects are particularly noticeable in the interior and the change from simulation 1 are marked for the informal sectors which now benefit directly from the infrastructure expansion whereas they previously benefitted only indirectly from the increase in the skilled labour force. The output effects drive quite different price effects. Prices for both sectors now fall, considerably for the informal sector. The effect of this is to reduce profits, although the increase in infrastructure offsets this downward pressure. The offset is less than complete for the informal sector in the coast which suffers a profit fall.

The wage and profit effects feed through to incomes which fall for both types of households in the coast but rise for interior households. Welfare still rises for both household types in both regions, and, as in simulation 1, by more in the interior than in the coast so that the welfare gaps narrows as shown by the disparity results in the last three rows of the table. The output and income gaps again widen. In all cases the change in the gap is larger than in simulation 1.

²⁰ Note that each regional government provides two types of infrastructure – one for the formal and one for the informal sector. We assume that the regional governments changes these in equal proportions so that $grf_{Fi} = grf_{Ni}$.

Thus, whether the regional governments use the additional revenue generated by the increase in the retirement age for general government consumption or for providing infrastructure has important implications for the overall economic effects, both for the nation as a whole and for the regions. The increase in productive capacity generated by the extra infrastructure increases output of both sectors in both regions and moderates wage declines for skilled workers. These ultimately feed through into welfare effects which are positive for both household types in both regions and are accompanied by a greater narrowing of the inter-regional welfare gap and a greater widening of output and income gaps.

4.4 Simulation 4: R_i endogenous in the regional governments' budget constraints

The increase in the retirement age increases net revenue for the regional governments since they pay fewer pensions and receive more pension premium income. In the current simulation, this additional revenue plus the benefits from lower government production costs are used to reduce the pension premium level in contrast to the previous cases where it was used to increase government expenditure. It can be seen from the final pair set of simulation results in Table 3 that the consequent fall in R is about 25% with the fall being larger in the interior. This reduction in the premium which skilled workers have to pay the regional government has powerful flow-on effects through the rest of the economy where we see that, by and large, the changes in endogenous variables are about two to three times the magnitudes of those simulation 1.

The increase in labour supply is what it was for simulation 1, both overall and by region. The increase in private employment of skilled labour is now much greater and the cause is not hard to find – now that government production is not the endogenous variable for the regional governments, they do not employ more labour for this as they did in the previous cases. This leaves more skilled labour to be absorbed by the private sector which increases

by 8.35% in the interior and 4.46% in the coast; so, as expected, the effect is still bigger in the interior. It is not surprising that the skilled wage falls by more than previously and, again, by more in the interior than in the coast: 8.91% and 6.03% respectively.

The production-cost effect for governments, which was so important in simulation 1, still works for the central government in the present case since we maintain the assumption that the central government varies its output of the consumption good to satisfy its budget constraint. The lower cost of production resulting from the lower skilled wage makes it possible to produce more GC and in simulation 4 this effect is stronger than in simulation 1 because of the larger fall in skilled wages. But the larger increase in GC is more than offset by the smaller expansion of output by the regional governments who now hold GRH exogenous and allow R to adjust to balance their budgets. The overall increase in GH is still positive but much smaller than in simulation 1.

There are larger effects on prices as is expected, following the bigger fall in the skilled wage. Output increases in each sector in each region by about two to three times the corresponding increases for simulation 1 because of the greater absorption of the extra skilled labour by the private sectors. As in the previous cases, the output effect in the interior is greater than it is in coastal region, given the larger increases in private sector employment of skilled labour in the interior.

As for simulation 1, income per household rises for unskilled households and falls for skilled households, with magnitudes being larger than in the previous case. These differences reflect different wage responses outlined above but also different profit effects: profit changes have the same signs as previously (positive for the informal sector and negative for the formal sector) but the magnitudes are bigger. The relative regional magnitudes are the same as before and this flows through into profit distribution to households – the formal-sector

effects flow through to the skilled households and the informal-sector effects flow through to the unskilled households.

The utility of all four household groups increases and does so by more than in the case of simulation 1, except for skilled households in the coast for which the increase is slightly smaller. As in the previous case, the increase in welfare in the interior is greater than in the coast, thus reducing the welfare disparity between the regions (although by less than in the case of simulation 1). Regional disparities in welfare are reduced in the short run, as they were in the previous simulation, although the narrowing is less pronounced. It is interesting that, in contrast to the case of simulation 1, disparities in per capita output and household income are also reduced in the short run so that the shock in simulation 4 is the only one which has beneficial short-run effects on all three disparity measures.

In summary, compared to simulation 1, in the short run all four household groups are better-off generally by a larger margin than they were in the previous simulation. In the long run this is reversed for the skilled households in the coast – the migration from the interior reduces incomes to such an extent that they are worse-off than they were in the initial equilibrium. Moreover, general effects on economic variables such as output are two to three times the magnitude in simulation 4 compared to simulation 1. It seems that, on the whole, it is better to return the extra net revenue to the workers in terms of lower pension premia rather than to use it for the provision of extra government consumption goods.

An alternative closure for the regional government budgets is to assume that the extra revenue is returned to retirees in the form of a higher pension, rather than to employed skilled workers as lower pension premia. The effects of an increase in the retirement age are the same under this assumption as they are in the previous case (except, of course, for the effects

on pensions and pension premia themselves). Thus it makes no difference to the national or regional economies whether the extra revenue is returned to retirees or to skilled workers.²¹

5. Conclusions

This paper has considered the regional economic effects of an increase in the retirement age in China within the context of a small theoretical model with some important Chinese characteristics. We solved the model numerically using parameter values derived from average Chinese data for the period 2008-2013. We focussed on the regional aspects of the effects of a change in the retirement age, focussing, in particular, on the effect of the policy on existing inter-regional disparities.

We carried out four experiments, all of which involved shocks designed to mimic an increase in the retirement age from 60 to 61. Raising the retirement age generates extra revenue for the regional governments which were assumed ultimately responsible for the payment of pensions and the four experiments differed according to the assumption made about the use of this extra revenue. In the first it was assumed that the regional governments used the extra net revenue for the provision of a government- provided consumption good; in the second we made a similar assumption but imposed shocks which we uniform across the two regions; in the third we assumed that the revenue was used for boosting infrastructure expenditure while in the fourth case it was assumed that the government used the revenue to reduce pension premia (or increase pension payments).

²¹ Analytically, this can be seen by noting that the two terms W_{Ri} and R_i appear only in equations (3) and (10) and in both of these equations can be written in the form: $r_iW_{Ri} - (1 - r_i)R_i$ which we may interpret as the net pension payments. It is only this composite term, not the individual components, which affects the rest of the economy. This follows from the representative household assumption that assumes each skilled household to be composed of $(1-r_i)$ workers and r_i retirees. In practice this will not be the case and there aril be (at least) quite different consequences for the inter-generational distribution of income of the two alternatives.

In all cases the result of raising the retirement age was to increase skilled labour supply (only skilled workers have pension coverage) and to reduce the skilled wage in both regions. Both of these effects were generally larger in the interior than in the coast since the reduction in the retirement age had a greater initial impact on the interior due to demographic differences.

All four simulations showed an increase in welfare for both household types, in both regions. Generally the welfare increase was greater for the unskilled households, with the exception being where the extra revenue was used for infrastructure. From a regional perspective, the welfare improvement was always greater in the interior than in the coast, resulting in a narrowing of the welfare disparity between the two regions for all simulations. The effects of the policy on the other measures of disparities (income and output per capita) was less consistent across simulations; generally, in the short run at least, income and output disparities widened as a result of the retirement-age increase; the clear exception was where the additional revenue was returned to skilled households in the form of reduced pension premia or increased pension payments. In this case all three measures of inter-regional disparities showed a narrowing of the gap between the regions.

Thus from a welfare perspective, a reduction in the retirement age seems an attractive policy -- in all the forms examined in this paper it increases welfare for all groups and reduces the welfare gap between the regions. However, if more visible measures of the inter-regional gap such as income or per capita output are preferred, the verdict is less clear since then there are losers as well as winners and the losers can be expected to resist the introduction of the policy. This is especially so since the losers are often the skilled whose wages and incomes fall as a result of the expansion of the skilled labour force. Moreover, the analysis ignores the disutility of the skilled workers' working longer (or the utility of retirement) which may further set the skilled households against the policy.

- Alonso, J., Caballero, M. A., Hui, L., Llanes, M. C., Tuesta, D., Hu, Y. and Cao, Y. (2011), "Potential Outcomes of Private Pension Developments in China", *BBVA Working Papers* Number 11/33.
- Bao, S., Bodvarsson, O., Hou, J. and Zhao, Y. (2011), "The Regulation of Migration in A Transition economy: China's Hukou System", *Contemporary Economic Policy*, 29(4): 564–579.
- Barr, N. and Diamond, P. (2008), "China: The Pension System", Chapter 14 in Barr, N. and Diamond, P., *Reforming Pensions: Principles and Policy Choices*, Oxford University Press, Oxford.
- Barr, N. and Diamond, P. (2010), "Pension Reform in China: Issues, Options and Recommendations". China Economic Research and Advisory Programme.
- Behaghel, L. and Blau, D. (2012), "Framing Social Security Reform: Behavioral Responses to Changes in the Full Retirement Age", *American Economic Journal: Economic Policy*, 4, 41-67.
- Cai, F. (2008), "Rethinking China's Pension Reform: The Relevance of International Experiences", *China Economist*, 2008 Nov-Dec: 44-53.
- Cai, Y. and Cheng, Y. (2014), "Pension Reform in China: Challenges and Opportunities", *Journal of Economic Surveys*, 28(4): 636–651.
- Chen, A. and Groenewold, N. (2013), "Does Investment Allocation Affect the Inter-Regional Output Gap in China?", *China Economic Review*, 26: 197-206.
- Chen, A. and Groenewold, N. (2014), "The Regional Economic Effects of a Reduction in Carbon Emission and an Evaluation of Offsetting Policies in China", *Papers in Regional Science*, 93(2): 429-453.
- Cheng, T. and Selden, M. (1994), "The Origins and Consequences of China's Hukou System", *The China Quarterly*, 139: 644-668.
- Dorfman, M. C., Holzmann, R., O'Keefe, P., Wang, D., Sin, Y. and Hinz, R.(2013), *China's Pension System: A Vision*, The World Bank, Washington, D.C.
- Fitzpatrick, M. and Lovenheim, M. (2014), "Early Retirement Incentives and Student Achievement", *American Economic Journal: Economic Policy*, 6, 120-54.
- Fleisher B., Li, H. and Zhao, M. (2010), "Human Capital, Economic Growth, and Regional Inequality in China", *Journal of Development Economics*, 92: 215-231.
- Giles, J., Wang, D. and Cai, W.(2011), "The Labor Supply and Retirement Behavior of China's Older Workers and Elderly in Comparative Perspective", The World Bank, *Policy Research Working Paper 5853*.
- He, C., Wei, Y. D. and Xie, X. (2008), 'Globalization, Institutional Change, and Industrial Location: Economic Transition and Industrial Concentration in China', *Regional Studies*, 42: 923-945.
- Herd, R., Hu, Y. and Koen, V. (2010), "Providing Greater Old-Age Security in China", OECD Economics Department Working Papers. No.750.
- Herrerías, M. J. and Monfort, J. O. (2015), "Testing Stochastic Convergence across Chinese Provinces, 1952–2008", *Regional Studies*, 49(4): 485-501.

- Jia, J., Guo, Q. and Zhang, J. (2014), "Fiscal Decentralization and Local Expenditure Policy in China", *China Economic Review*, 28: 107-122.
- Jin, H., Qian, Y. and Weingast, B. R. (2005), "Regional Decentralization and Fiscal Incentives: Federalism Chinese Style", *Journal of Public Economics*, 89: 1719-1742.
- Krugman, P. R. (1991), "Increasing Returns and Economic Geography", *Journal of Political Economy*, 99: 483-99.
- Li, H. and Merette, M. (2005), "Population Ageing and Pension System Reform in China: A Computable Overlapping-Generations General Equilibrium Model Analysis", *Journal* of Chinese Economic and Business Studies, 3: 263–277.
- Lin, P., Lin, C. and Ho, I. (2013), "Regional Convergence or Divergence in China? Evidence from Unit Root Tests with Breaks", *Annals of Regional Science*, 50: 223-243.
- Novy-Marx, R. and Rauh, J. (2014), "The Revenue Demands of Public Employee Pension Promises", *American Economic Journal: Economic Policy*, 6, 193-229.
- Pissarides, C. A. and McMaster, I. (1990), "Regional Migration, Wages and Unemployment: Empirical Evidence and Implications for Policy", Oxford Economic Papers, 42: 812-831.
- Rada, C.(2010), "Formal and Informal Sectors in China and India", *Economic Systems Research*, 22(2):129–153.
- Rizov, M. and Zhang, X. (2014), "Regional Disparities and Productivity in China: Evidence from Manufacturing Data", *Papers in Regional Science*, 93(2): 321-339.
- Shen, C., Jin, J. and Zou, H. (2012), "Fiscal Decentralization in China: History, Impacts, Challenges and Next Steps", *Annals of Economics and Finance*, 13: 1-51.
- Shen, C. and Zou, H. (2015), "Fiscal Decentralization and Public Services Provision in China", *Annals of Economics and Finance*, 16: 53-78.
- Song, S.(2009), "Pension Systems and Reforms in China and Russia", *The Chinese Economy*, 42(3): 9–23.
- Song, Z., Storesletten, K., Wang Y. and Zilibotti F. (2015), "Sharing High Growth across Generations: Pensions and Demographic Transition in China", *American Economic Journal: Macroeconomics*, 7(2): 1–39.
- Su, J. and Jefferson, G. H.(2012), "Differences in Returns to FDI between China's Coast and Interior: One Country, Two Economies?", *Journal of Asian Economics*, 23: 259-269.
- Tochkov, K. (2007), "Interregional Transfers and the Smoothing of Provincial Expenditure in China", *China Economic Review*, 18: 54-65.
- Wang, L., Beland, D. and Zhang, S. (2014a), "Pension Fairness in China", *China Economic Review*, 28: 25–36.
- Wang, L., Beland, D. and Zhang, S. (2014b), "Pension Financing in China: Is There a Looming Crises?", *China Economic Review*, 30: 143-154.
- Whalley, J. and Zhang, S. (2007), "A Numerical Simulation Analysis of (Hukou) Labour Mobility Restrictions in China", *Journal of Development Economics*, 83: 392-410.
- Woodland, A.D. and Yoshida, C.(2006), "Risk Preference, Immigration Policy and Illegal Immigration", *Journal of Development Economics*, 81: 500–513.

- Zeng, Y. (2011), "Effects of Demographic and Retirement-Age Policies on Future Pension Deficits, with an Application to China", *Population & Development Review*, 37(3): 553–569.
- Zhang, W. (2007), "Further Reform of China's Pension System: A Realistic Alternative Option to Fully Funded Individual Accounts", *Asian Economic Papers*, 6: 112-135.
- Zhang, X. (2006), "Fiscal Decentralization and Political Centralization in China: Implications for Growth and Inequality", *Journal of Comparative Economics*, 34: 713-726.
- Zhang, Z. and Martinez-Vazquez, J. (2003), "The System of Equalizing Transfers in China", International Studies Program Working Paper 03-12, Andrew Young School of Policy Studies, Georgia State University.
- Zheng, B.(2007), "The Origin of China's Partially Funded Social Security Scheme and Its Future Direction", *The Chinese Economy*, 40(4): 6-28.

Region	Year	GDP Per Capita (Yuan)	Share of Urban Population (%)	Share of Retired Persons (%)	Life Expectancy
Interior	2000	5407.45	0.31	0.41	69.52
Coastal	2000	11559.61	0.45	0.34	73.97
Interior	2005	10392.95	0.37	0.28	
Coastal	2005	22179.54	0.52	0.23	
Interior	2010	24062.88	0.44	0.30	73.52
Coastal	2010	44108.68	0.59	0.21	77.10
Interior	2013	35780.05	0.48	0.31	
Coastal	2013	59913.61	0.62	0.21	

Table 1 Inter-Regional Disparities

Source: China Statistical Year Book (SSB, various issues)

Variable	Y_N	\mathbf{Y}_{F}	L _{NU} (10,000)	L _{FU} (10,000)	L _{FS} (10,000)	L _S (10,000)	Ws
Interior	33137.17	62413.27	24703.00	5484.43	6901.73	12398.30	2.23
Coast	40638.33	97221.28	16469.34	7412.12	7603.00	11109.72	3.34
Variable	r (%)	R	W _R	$T_{N} = T_{F}$ (%)	GRH	GRF _F	GRF _N
Interior	29.45	0.47	0.88	4.18	0.03	457.45	824.28
Coast	23.68	0.39	0.99	4.18	0.04	464.45	668.99
Variable	IIF _N	IIF _F	IIH _U	IIHs	L _U (10,000)	Q _U (10,000)	Qs (10,000)
Interior	7049.78	38958.69	0.23	2.22	30187.44	30187.44	17574.28
Coast	22471.21	60362.05	0.94	4.15	23881.45	23881.45	14556.47
Variable	$J_{\rm U}$	J _S	L _{GRS}	L _{GCS}	T _V (%)	GC	GH
Interior	1.23	3.71	2927.78	2568.79	4.88	0.05	0.09
Coast	1.94	6.63	2528.47	978.26	4.88	0.03	0.06
Variable	C _{NU}	C _{FU}	C _{NS}	C _{FS}	P _N =P _F	P _{GR} =P _{GC}	θ
Interior	0.35	0.82	1.06	2.47	1.00	2.23	0.75
Coast	0.55	1.29	2.15	4.16	1.00	3.34	0.75

Table 2 Data for the Main Variables, China, 2008-2013 (average)

Source: China Statistical Year Book (SSB, various issues)

Notes: output, wage, pension premium, pension income and government expenditure are in terms of unskilled labour.

xx · 11		ation 1:		Simulation 2:		Simulation 3:		Simulation 4:	
Variables	GRH endogenous		Equal shocks		GRF endogenous		<i>R</i> endogenous		
	SR	LR	SR	LR	SR	LR	SR	LR	
V _{UI}	1.6435	1.6555	1.5918	1.5823	1.3018	1.2868	2.0377	2.2356	
v_{UC}	1.0658	1.0838	1.1332	1.1189	1.0126	0.9973	2.1193	2.2527	
<i>v_{SI}</i>	0.6280	0.7249	0.5225	0.4457	1.7345	1.6037	1.2758	2.0288	
v _{SC}	0.2985	0.1614	0.3785	0.4872	1.3003	1.4860	0.2975	-0.8176	
gh_I	14.2800	14.1884	13.0524	13.1251	1.1847	1.1785	4.3415	4.3083	
gh_C	10.4619	10.6279	11.8098	11.6782	0.8012	0.7971	2.9362	2.9138	
jui	0.0203	0.0232	0.0255	0.0232	0.0216	0.0194	0.0358	0.0678	
<i>j</i> uc	0.0788	0.0749	0.0718	0.0750	-0.2695	-0.2715	0.2633	0.2186	
jsı	-0.3858	-0.3011	-0.4947	-0.5618	0.4592	0.3388	-0.6294	-0.0401	
jsc	-0.4322	-0.5880	-0.3941	-0.2704	-0.0337	0.1657	-1.4440	-2.7415	
p_N	0.0402	0.0417	0.0429	0.0417	-2.1428	-2.1571	0.1053	0.1216	
p_F	-0.9783	-1.0031	-1.0245	-1.0048	-0.9232	-0.8977	-2.6575	-2.9264	
У _{NI}	0.1408	0.1460	0.1503	0.1462	3.1976	3.2530	0.3690	0.4262	
УNC	0.0294	0.0305	0.0314	0.0306	0.3977	0.3415	0.0772	0.0892	
УFI	0.5680	0.5160	0.4758	0.5171	1.3512	1.4284	2.0919	1.5044	
У _{FC}	0.5242	0.5777	0.6214	0.5790	0.9689	0.8868	1.0899	1.6844	
WSI	-2.7681	-2.6697	-2.5969	-2.6749	-1.9527	-2.0871	-8.9110	-7.7861	
w _{SC}	-2.5105	-2.6697	-2.8012	-2.6749	-2.2871	-2.0871	-6.0250	-7.7861	
l _{FSI}	2.3578	2.1826	2.0483	2.1872	2.3807	2.6177	8.3454	6.3640	
l _{FSC}	2.0564	2.2443	2.3981	2.2491	2.3328	2.0762	4.4575	6.5441	
l _{GCSI}	2.4513	2.3903	2.4271	2.4754	2.5385	2.6385	7.3038	6.7118	
l _{GCSC}	2.3471	2.4211	2.3443	2.2855	1.2049	1.0580	6.8993	7.5127	
l _{GRSI}	18.4737	18.3086	16.7140	16.8449	18.3432	18.5827	0.1014	-0.2008	
l _{GRSC}	8.8575	9.0549	10.1349	9.9784	8.4683	8.1868	-0.1236	0.2449	
l _{SI}	6.1828	6.0337	5.5900	5.7083	6.1828	6.3921	6.1828	4.8858	
l _{SC}	3.6299	3.8099	4.1542	4.0114	3.6299	3.3772	3.6299	5.1957	
Output disparities	0.0098	-0.0564	0.1118	0.1643	0.2061	0.3109	-0.4423	-0.8758	
Income disparities	0.0192	-0.0543	0.1005	0.1587	0.1955	0.3095	-0.3185	-0.8444	
Welfare disparities	-0.5605	-0.6588	-0.4231	-0.3451	-0.7721	-0.6487	-0.2090	-1.1236	

Table 3Simulation Results

Notes: lower-case letters represent the proportional changes (log differential) of their upper-case counterparts. "*Output disparities*" equals $(y_C-q_C)-(y_I-q_I)$, "*Income disparities*" equals j_C-j_I and "*Welfare disparities*" equals v_C-v_I . "SR" and "LR" are abbreviations of "short run" and "long run". The shock is set to -0.1481 for r_I and -0.1170 to r_C .

Appendix 1: Definition of variables

 C_{Fki} = real private consumption of the formal-sector good per household of type k, region i, C_{Nki} = real private consumption of the informal-sector good per household of type k, region i, D_{ii} = productivity parameter, sector *j*, region *i*, GC_i = real central government-provided consumption good per household, region *i*, GH_i = real government-provided consumption per household, region *i*, GRF_{ii} = real regional government-provided public infrastructure, sector *j*, region *i*, GRH_i = real regional government-provided consumption good per household, region *i*, J = national income per household, J_i = real income per household, region *i*, J_{ki} = real income per household of type k, region i, L_{GCSi} = skilled labour hired by the central government in region *i*, L_{GRSi} = skilled labour hired by the regional government in region *i* L_{jki} = employment, sector *j*, type *k*, region *i*. L_{ki} = employment, type k, region i, P_F = price of the formal-sector good in terms of unskilled labour, P_{GCi} = price of the central government-provided consumption good in terms of unskilled labour, region *i*, P_{GRi} = price of the regional government-provided good in terms of unskilled labour, region *i*, P_N = price of the informal-sector good in terms of unskilled labour, Q = national population, Q_i = population, region *i*, Q_k = population, type k, Q_{ki} = population, type k, region i, r_i = proportion of skilled workers retired, region *i*, R_i = real pension premium per skilled worker, region *i*, T_{ii} = output tax rate, sector *j*, region *i*, T_{v} = value added tax rate, V = national utility, V_i = utility of the representative household, region *i*, V_{ki} = utility of the representative household of type k, region i, W_{Ri} = real pension of retired skilled worker, region *i*, W_{Si} = real wage of skilled worker, region *i*, Y = national real output, Y_i = real output, region *i*, Y_{ii} = real output, sector *j*, region *i*, θ = central government's share of valued-added tax,

 ΠH_{ki} = real profit distribution per household of type k, region i,

 Π_{ji} = real profit, sector *j*, region *i*.

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 (20) 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') $v_{ki} = \sigma_{VCNki}c_{Nki} + \sigma_{VCFki}c_{Fki} + \sigma_{VGHki}gh_i$ i=I, C; k=U, Swhere lower-case letters represent the proportional changes (log differential) of their uppercase counterparts and

$$\sigma_{VCNki} = \frac{\gamma_{Nki}C_{Nki}^{-\rho_{ki}}}{\gamma_{Nki}C_{Nki}^{-\rho_{ki}} + \gamma_{Fki}C_{Fki}^{-\rho_{ki}} + \gamma_{Gki}GH_{i}^{-\rho_{ki}}},$$

$$\sigma_{VCFki} = \frac{\gamma_{Fki}C_{Fki}^{-\rho_{ki}}}{\gamma_{Nki}C_{Nki}^{-\rho_{ki}} + \gamma_{Fki}C_{Fki}^{-\rho_{ki}} + \gamma_{Gki}GH_{i}^{-\rho_{ki}}},$$

$$\sigma_{VGHki} = \frac{\gamma_{Gki}GH_{i}^{-\rho_{ki}}}{\gamma_{Nki}C_{Nki}^{-\rho_{ki}} + \gamma_{Fki}C_{Fki}^{-\rho_{ki}} + \gamma_{Gki}GH_{i}^{-\rho_{ki}}}.$$
The demand function:

The demand function:

(2a')
$$c_{Nki} = j_{ki} - \sigma_{TV}t_V - p_N + \sigma_{CCNki}(p_N - p_F)$$
 $i=I, C; k=U, S$

where
$$\sigma_{CCNki} = \frac{\frac{\rho_{ki}}{1+\rho_{ki}} (\frac{\gamma_{Fki}}{\gamma_{Nki}})^{\overline{1+\rho_{ki}}} (\frac{P_N}{P_F})^{\overline{1+\rho_{ki}}}}{1+(\frac{P_N}{P_F})^{\overline{1+\rho_{ki}}} (\frac{\gamma_{Fki}}{\gamma_{Nki}})^{\frac{1}{1+\rho_{ki}}}}, \ \sigma_{TV} = \frac{T_V}{1-T_V}.$$

(2b')
$$c_{Fki} = j_{ki} - \sigma_{TV} t_V - p_F + \sigma_{CCFki} (p_F - p_N)$$
 $i=I, C; k=U, S$
where $\sigma_{CCFki} = \frac{\frac{\rho_{ki}}{1 + \rho_{ki}} (\frac{\gamma_{Nki}}{\gamma_{Fki}})^{\frac{1}{1 + \rho_{ki}}} (\frac{P_F}{P_N})^{\frac{-\rho_{ki}}{1 + \rho_{ki}}}}{1 + (\frac{P_F}{P_N})^{\frac{-\rho_{ki}}{1 + \rho_{ki}}} (\frac{\gamma_{Nki}}{\gamma_{Fki}})^{\frac{1}{1 + \rho_{ki}}}}.$

The definitions of real household income are: (3a') $i_{\mu\nu} = \sigma_{\mu\mu\nu}\pi h_{\mu\nu}$ i=I, C

where
$$\sigma_{JPUi} = \sigma_{JPUi} \prod_{i} \sigma_{WRWi} = \frac{\Pi H_{Ui}}{J_{Ui}}$$
.
(3b') $j_{Si} = \sigma_{JWRi} (\sigma_{WRWi} w_{Si} - \sigma_{WRRi} \hat{r}_i - \sigma_{ri} r_i^*) + \sigma_{JWWi} (w_{Ri} + r_i^*) + \sigma_{JPSi} \pi h_{Si}$ $i=I, C$
where $\sigma_{JWRi} = \frac{(1 - r_i)(W_{Si} - R_i)}{J_{Si}}, \sigma_{JWWi} = \frac{r_i W_{Ri}}{J_{Si}}, \sigma_{JPSi} = \frac{\Pi H_{Si}}{J_{Si}},$
 $\sigma_{WRWi} = \frac{W_{Si}}{W_{Si} - R_i}, \sigma_{WRRi} = \frac{R_i}{W_{Si} - R_i}, \sigma_{ri} = \frac{r_i}{1 - r_i}, r^* = dr/r.$
The skilled labor migration equation:
 $(A^2) = w_i + \sigma_i u^*$

(4')
$$w_{SC} = w_{SI} + \sigma_{\mu}\mu^{*}$$

where $\sigma_{\mu} = \frac{\mu}{1+\mu}$, $\mu^{*} = \frac{d\mu}{\mu}$.
The production function:
(5a') $y_{Ni} = d_{Ni} + \alpha_{NUi}l_{NUi} + \alpha_{NGi}grf_{Ni}$ $i=I, C$

(5b') $y_{Fi} = d_{Fi} + \alpha_{FSi}l_{FSi} + \alpha_{FUi}l_{FUi} + \alpha_{FGi}grf_{Fi}$ *i=I*, *C* The profit function: (6a') $\pi_{Ni} = \sigma_{PNYi}(y_{Ni} + p_N - \sigma_{TNi}t_{Ni}) - \sigma_{PNIi}l_{NI/i}$ i=I, Cwhere $\sigma_{PNYi} = \frac{(1 - T_{Ni})Y_{Ni}P_N}{\Pi_{Ni}}, \ \sigma_{TNi} = \frac{T_{Ni}}{1 - T_{Ni}}, \ \sigma_{PNLi} = \frac{L_{NUi}}{\Pi_{Ni}}.$ (6b') $\pi_{Fi} = \sigma_{PFYi}(y_{Fi} + p_F - \sigma_{TFi}t_{Fi}) - \sigma_{PFLII}l_{FIII} - \sigma_{PFLSI}(\mathbf{w}_{Si} + l_{FSI})$ i=I, Cwhere $\sigma_{PFY_i} = \frac{(1 - T_{F_i})Y_{F_i}P_F}{\prod_{F_i}}, \ \sigma_{TF_i} = \frac{T_{F_i}}{1 - T_{F_i}}, \ \sigma_{PFLU_i} = \frac{L_{FU_i}}{\prod_{F_i}}, \ \sigma_{PFLS_i} = \frac{W_{S_i}L_{FS_i}}{\prod_{F_i}}.$ The labour demand function: (7a') $y_{Fi} + p_F - \sigma_{TFi} t_{Fi} = w_{Si} + l_{FSi}$ *i=I*, *C* (7b') $y_{Fi} + p_F - \sigma_{TFi} t_{Fi} = l_{FUi}$ *i*=*I*, *C* (7c') $y_{Ni} + P_N - \sigma_{TNi} t_{Ni} = l_{NUi}$ *i=I*, C Central government production and budget constraint: $(8') \quad q_i + gc_i = l_{GCSi} \quad i=I, C$ (9') $\sigma_{GCI}(q_I + p_{GCI} + gc_I) + \sigma_{GCC}(q_C + p_{GCC} + gc_C) = \theta^* + t_{\nu}$ $+\sigma_{ISI}(q_{SI}+j_{SI})+\sigma_{III}(q_{III}+j_{III})+\sigma_{ISC}(q_{SC}+j_{SC})+\sigma_{IIIC}(q_{IIC}+j_{IIC})$ where $\sigma_{GCI} = \frac{Q_I P_{GCI} G C_I}{Q_I P_{GCI} G C_I + Q_C P_{GCC} G C_C}$, $\sigma_{GCC} = \frac{Q_C P_{GCC} G C_C}{Q_I P_{GCI} G C_I + Q_C P_{GCC} G C_C}$ $\sigma_{JSI} = \frac{Q_{SI}J_{SI}}{Q_{SI}J_{SI} + Q_{UI}J_{UI} + Q_{SC}J_{SC} + Q_{UC}J_{UC}}, \ \sigma_{JUI} = \frac{Q_{UI}J_{UI}}{Q_{SI}J_{SI} + Q_{UI}J_{UI} + Q_{SC}J_{SC} + Q_{UC}J_{UC}},$ $\sigma_{JSC} = \frac{Q_{SC}J_{SC}}{Q_{SI}J_{SI} + Q_{UI}J_{UI} + Q_{SC}J_{SC} + Q_{UC}J_{UC}}, \ \sigma_{JUC} = \frac{Q_{UC}J_{UC}}{Q_{SI}J_{SI} + Q_{UI}J_{UI} + Q_{SC}J_{SC} + Q_{UC}J_{UC}},$ $\theta^* = d\theta/\theta.$ The regional government budget constraint and production: (10') $\sigma_{OGRHi}(q_i + p_{GRi} + grh_i) + \sigma_{GRFNi}(grf_{Ni} + p_{GRi})$ *i=I*, *C* $+\sigma_{GRFFi}(grf_{Fi}+p_{GRi})+\sigma_{GROWi}(r_i^*+q_{Si}+w_{Ri})$ $=\sigma_{GRTE}(-\sigma_{\theta}\theta^{*}+t_{v}+\sigma_{IOSi}(q_{Si}+j_{Si})+\sigma_{IOUi}(q_{E}+j_{E}))$ $+\sigma_{GRYNi}(t_{Ni}+p_N+y_{Ni})+\sigma_{GRYFi}(t_{Fi}+p_F+y_{Fi})+\sigma_{GRORi}(q_{Si}+\hat{r}_i-\sigma_{i}r_i^*)$ where $\sigma_{QGRHi} = \frac{Q_i P_{GRi} GRH_i}{Q_i P_{GRi} GRH_i + P_{GRi} GRF_{Ni} + P_{GRi} GRF_{Fi} + r_i Q_{Si} W_{Ri}}$ $P_{CRi}GRF_{Ni}$ $\sigma_{GRFNi} = \frac{1}{Q_i P_{GRi} GRH_i + P_{GRi} GRF_{Ni} + P_{GRi} GRF_{Fi} + r_i Q_{Si} W_{Ri}}$ $\sigma_{GRFFi} = \frac{P_{GRi}GRF_{Fi}}{Q_i P_{GRi}GRH_i + P_{GRi}GRF_{Ni} + P_{GRi}GRF_{Fi} + r_i Q_{Si} W_{Ri}}$ $\sigma_{GRQWi} = \frac{r_i Q_{Si} W_{Ri}}{Q_i P_{GRi} GRH_i + P_{GRi} GRF_{Ni} + P_{GRi} GRF_{Fi} + r_i Q_{Si} W_{Ri}}$ $\sigma_{GRTJi} = \frac{(1-\theta)T_V(Q_{Si}J_{Si} + Q_{Ui}J_{Ui})}{T_{Ni}P_NY_{Ni} + T_{Fi}P_FY_{Fi} + (1-r_i)Q_{Si}R_i + (1-\theta)T_V(Q_{Si}J_{Si} + Q_{Ui}J_{Ui})},$ $\sigma_{JQSi} = \frac{Q_{Si}J_{Si}}{Q_{Si}J_{Si} + Q_{II}J_{II}}, \ \sigma_{JQUi} = \frac{Q_{Ui}J_{Ui}}{Q_{Si}J_{Si} + Q_{II}J_{II}},$

$$\begin{split} \sigma_{GRIM} &= \frac{T_{M}P_{N}Y_{Ni}}{T_{Ni}P_{N}Y_{Ni} + T_{Fi}P_{F}Y_{Fi} + (1-r_{i})Q_{Si}R_{i} + (1-\theta)T_{V}(Q_{Si}J_{Si} + Q_{Ui}J_{Ui})}, \\ \sigma_{GRVFi} &= \frac{T_{Fi}P_{F}Y_{Fi}}{T_{Ni}P_{N}Y_{Ni} + T_{Fi}P_{F}Y_{Fi} + (1-r_{i})Q_{Si}R_{i} + (1-\theta)T_{V}(Q_{Si}J_{Si} + Q_{Ui}J_{Ui})}, \\ \sigma_{GRQEi} &= \frac{(1-r_{i})Q_{Si}R_{i}}{T_{Ni}P_{N}Y_{Ni} + T_{Fi}P_{F}Y_{Fi} + (1-r_{i})Q_{Si}R_{i} + (1-\theta)T_{V}(Q_{Si}J_{Si} + Q_{Ui}J_{Ui})}, \\ \sigma_{\theta} &= \frac{\theta}{1-\theta}. \\ (11') \quad \sigma_{LGRHi}(q_{i} + grh_{i}) + \sigma_{LGNi}grf_{Ni} + \sigma_{LGFi}grf_{Fi} = l_{GRSi} \quad i=l, C \\ \text{where } \sigma_{LGRHi} &= \frac{Q_{i}GRH_{i}}{L_{GRSi}}, \quad \sigma_{LGNi} &= \frac{GRF_{Ni}}{L_{GRSi}}, \quad \sigma_{LGFi} &= \frac{GRF_{Fi}}{L_{GRSi}}. \\ \text{The price of the government good \\ (12a') \quad p_{GCi} = w_{Si} \quad i=l, C \\ (12b') \quad p_{GRi} = w_{Si} \quad i=l, C \\ (12b') \quad p_{GRi} = w_{Si} \quad i=l, C \\ \text{The definition of regional and national output } \\ (13a') \quad y_{i} = \sigma_{IPN}(p_{N} + y_{N}) + \sigma_{IPFi}(p_{F} + y_{Fi}) \quad i=l, C \\ \text{where } \sigma_{IPNi} &= \frac{P_{N}Y_{Ni}}{P_{N}Y_{Ni} + P_{F}Y_{Fi}}, \quad \sigma_{IPFi} = \frac{P_{F}Y_{Fi}}{P_{N}Y_{Ni} + P_{F}Y_{Fi}}, \text{ and } \\ (13b') \quad y = \sigma_{IPI}y_{i} + \sigma_{YPC}y_{C} \\ \text{where } \sigma_{ITT} &= \frac{Y_{I}}{Y_{I} + Y_{C}}, \quad \sigma_{ITC} = \frac{Y_{C}}{Y_{I} + Y_{C}}. \\ \text{The definition of regional and national income: } \\ (14a') \quad j_{i} + q_{i} = \sigma_{IQUi}(j_{Ui} + q_{Ui}) + \sigma_{IQSi}(j_{Si} + q_{Si}) \quad i=l, C \\ (14b') \quad j + q = \sigma_{III}(j_{I} + q_{I}) + \sigma_{IIC}(j_{C} + q_{C}) \\ \text{where } \sigma_{III} &= \frac{Q_{I}J_{I}}{Q_{I}J_{I} + Q_{C}J_{C}}, \quad \sigma_{IIC} = \frac{Q_{C}J_{C}}{Q_{I}J_{I} + Q_{C}J_{C}}. \\ \text{The definition of regional and national utility: \\ (15a') \quad v_{i} + q_{i} = \sigma_{VQUi}(q_{Ui} + v_{Ui}) + \sigma_{VQSi}(q_{Si} + v_{Si}) \quad i=l, C \\ \text{where } \sigma_{UUi} &= \frac{Q_{I}J_{U}}{Q_{U}V_{Ui} + Q_{S}V_{Si}}, \quad \sigma_{VQSi} = \frac{Q_{S}V_{Si}}{Q_{Ui}V_{Ui} + Q_{S}V_{Si}}, \text{ and } \\ (15b') \quad v_{I} = \sigma_{VUI}(v_{I} + q_{I}) + \sigma_{VVC}(v_{C} + q_{C}) \\ \text{where } \sigma_{VUI} &= \frac{Q_{U}V_{Ui}}{Q_{U}V_{Ui} + Q_{S}V_{Si}}, \quad \sigma_{VQSi} = \frac{Q_{S}V_{Si}}{Q_{Ui}V_{Ui} + Q_{S}V_{Si}}, \text{ and } \\ (15b') \quad v_{I} = \sigma_{GIGRBI}grh_{I} +$$

 $=\sigma_{CNUI}(q_{UI}+c_{NUI})+\sigma_{CNSI}(q_{SI}+c_{NSI})+\sigma_{CNUC}(q_{UC}+c_{NUC})+\sigma_{CNSC}(q_{SC}+c_{NSC})$

where
$$\sigma_{TFM} = \frac{Y_{M}}{Y_{N} + Y_{NC}}$$
, $\sigma_{TFMC} = \frac{Y_{MC}}{Y_{M} + Y_{NC}}$,
 $\sigma_{CNUI} = \frac{Q_{UI}C_{NUI} + Q_{UI}C_{NSI} + Q_{UC}C_{VUC} + Q_{SC}C_{NSC}}{Q_{UI}C_{NUI} + Q_{SI}C_{NSI} + Q_{UC}C_{NUC} + Q_{SC}C_{NSC}}$,
 $\sigma_{CNNI} = \frac{Q_{UC}C_{NUI} + Q_{SI}C_{NSI} + Q_{UC}C_{NUC} + Q_{SC}C_{NSC}}{Q_{UI}C_{NUI} + Q_{SI}C_{NSI} + Q_{UC}C_{NUC} + Q_{SC}C_{NSC}}$,
 $\sigma_{CNUC} = \frac{Q_{UC}C_{NUI}}{Q_{UI}C_{NUI} + Q_{SI}C_{NSI} + Q_{UC}C_{NUC} + Q_{SC}C_{NSC}}$,
 $\sigma_{CNSC} = \frac{Q_{UC}C_{NUI}}{Q_{UI}C_{NUI} + Q_{SI}C_{NSI} + Q_{UC}C_{NUC} + Q_{SC}C_{NSC}}$,
(17b') $\sigma_{TTI}Y_{II} + \sigma_{TTPC}Y_{IC}$
 $= \sigma_{CTUI}(q_{UI} + c_{IUI}) + \sigma_{CTSI}(q_{SI} + c_{FSI}) + \sigma_{CTUC}(q_{UC} + c_{FUC}) + \sigma_{CFSC}(q_{SC} + c_{FSC})$
where $\sigma_{TTII} = \frac{Y_{II}}{Q_{UI}C_{FUI} + Q_{SI}C_{FSI}} + \sigma_{UC}C_{FUC} + Q_{SC}C_{TSC}}$,
 $\sigma_{CFUI} = \frac{Q_{UI}C_{FUI} + Q_{SI}C_{FSI} + Q_{UC}C_{FUC} + Q_{SC}C_{TSC}}{Q_{UI}C_{FUI} + Q_{SI}C_{FSI} + Q_{UC}C_{FUC} + Q_{SC}C_{FSC}}$,
 $\sigma_{CFUI} = \frac{Q_{UI}C_{FUI} + Q_{SI}C_{FSI} + Q_{UC}C_{FUC} + Q_{SC}C_{FSC}}{Q_{UI}C_{FUI} + Q_{SI}C_{FSI} + Q_{UC}C_{FUC} + Q_{SC}C_{FSC}}$,
 $\sigma_{CFUC} = \frac{Q_{UC}C_{FUI} + Q_{SI}C_{FSI} + Q_{UC}C_{FUC} + Q_{SC}C_{FSC}}{Q_{UI}C_{FUI} + Q_{SI}C_{FSI} + Q_{UC}C_{FUC} + Q_{SC}C_{FSC}}$,
Labour market-cleaning:
(18a1') $\sigma_{LNUI}N_{UI} + \sigma_{LTUI}I_{FUI} = I_{UI}$
(18a2') $\sigma_{LNUL}N_{UI} + \sigma_{LTUI}I_{FUI} = I_{UI}$
where $\sigma_{LAUC} = \frac{L_{NUC}}{L_{NUC} + L_{FUC}}$,
 $\sigma_{LIUC} = \frac{L_{NUC}}{L_{NUC} + L_{FUC}}$,
 $\sigma_{LIUI} = \frac{L_{NUI}}{L_{NUI} + L_{FUI}}$,
 $\sigma_{LICI} = \frac{L_{NUI}}{L_{FII} + L_{COS}} + L_{CGS}}$,
 $\sigma_{LICI} = \frac{L_{CSS}}{L_{FSI} + L_{CCSI} + L_{CGS}}$,
 $\sigma_{LICI} = \frac{L_{CSS}}{L_{FSI} + L_{CCSI} + L_{CGS}}$,
 $\sigma_{LICI} = \frac{L_{CSS}}{L_{FSI} + L_{CCSI} + L_{CGS}}$,

The labour supply and population definitions:

(19a') $l_{Ui} = q_{Ui}$ $i=I, C$
(19b') $l_{Si} = q_{Si} - \sigma_{ri} r_i^*$ <i>i=I</i> , <i>C</i>
(19c') $q_U = \sigma_{QUUI} q_{UI} + \sigma_{QUUC} q_{UC}$
where $\sigma_{QUUI} = \frac{Q_{UI}}{Q_{UI} + Q_{UC}}, \ \sigma_{QUUC} = \frac{Q_{UC}}{Q_{UI} + Q_{UC}}.$
(19d') $q_s = \sigma_{QSSI} q_{SI} + \sigma_{QSSC} q_{SC}$
where $\sigma_{QSSI} = \frac{Q_{SI}}{Q_{SI} + Q_{SC}}$, $\sigma_{QSSC} = \frac{Q_{SC}}{Q_{SI} + Q_{SC}}$.
$(19e1') q_I = \sigma_{QIUI} q_{UI} + \sigma_{QISI} q_{SI}$
where $\sigma_{QIUI} = \frac{Q_{UI}}{Q_{UI} + Q_{SI}}, \ \sigma_{QISI} = \frac{Q_{SI}}{Q_{UI} + Q_{SI}}.$
$(19e2') q_C = \sigma_{QCUC} q_{UC} + \sigma_{QCSC} q_{SC}$
where $\sigma_{QCUC} = \frac{Q_{UC}}{Q_{UC} + Q_{SC}}, \ \sigma_{QCSC} = \frac{Q_{SC}}{Q_{UC} + Q_{SC}}.$
$(19f') q = \sigma_{QQU} q_U + \sigma_{QQS} q_S$
where $\sigma_{QQU} = \frac{Q_U}{Q_U + Q_S}$, $\sigma_{QQS} = \frac{Q_S}{Q_U + Q_S}$.
Profit distribution function:
(20a') $\pi_{Ni} = q_{Ui} + \pi h_{Ui}$ <i>i=I</i> , <i>C</i>
(20b') $\pi_{Fi} = q_{Si} + \pi h_{Si}$ $i=I, C$

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_{jki} , γ_{Gki} , and ρ_{ki} appear in the utility function (1) and α_{jGi} and α_{jki} 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 $\sigma_{ki} = 1/(1+\rho_{ki})$ is derived from the equation:

$$\sigma_{ki} = \frac{\eta_{ki} - \gamma_{ki}^{\sigma_{ki}}}{1 - \gamma_{ki}^{\sigma_{ki}}}$$

where η_{ki} is the (uncompensated) own-price elasticity, values for which were derived as averages from Table 4 in Mansur and Whalley, and $\gamma_{ki}^{\sigma_{ki}}$ can be derived from ratios of consumption expenditure and our assumption that $\gamma_{Nki} + \gamma_{Fki} + \gamma_{Gki} = 1$.

The production function parameters were calibrated as follows. Normally we would use the firm's first-order condition for profit-maximisation, equation (7a), 7(b) and (7c) to write the parameters in terms of costs shares:

$$\alpha_{FSi} = \frac{W_{Si}L_{FSi}}{P_F Y_{Fi}(1 - T_{Fi})}, \alpha_{FUi} = \frac{L_{FUi}}{P_F Y_{Fi}(1 - T_{Fi})}, \alpha_{NUi} = \frac{L_{NUi}}{P_N Y_{Ni}(1 - T_{Ni})},$$

However, this is not strictly possible for the government infrastructure variable since it is not one of the firm's choice variables but is determined by the government and taken as parametric by the firms. If we assume, nevertheless, that the quantity of the infrastructure is chosen to maximise profits or that the government provides a profit-maximising amount, we can also write:

$$\alpha_{FGi} = \frac{GRF_{Fi}}{P_F Y_{Fi}(1 - T_{Fi})}$$
$$\alpha_{NGi} = \frac{GRF_{Ni}}{P_N Y_{Ni}(1 - T_{Ni})}.$$

We make this assumption and use data for the wage bill, government infrastructure expenditure and manufacturing output net of tax to compute the parameters.

The linearisation parameters can be evaluated directly from their definitions, given values for V_{ki} , C_{Nki} , C_{Fki} , GH_i , J_{ki} , P_j , ΠH_{Ui} , ΠH_{Si} , W_{Si} , Y_{Ni} , Y_{Fi} , L_{NUi} , L_{FUi} , L_{FSi} , Π_{Ni} , Π_{Fi} , L_{Ui} , Q_{Ui} , L_{Si} , Q_i , L_{GCSi} , L_{GRSi} , P_{GCi} , P_{GRi} , GC_i , GRH_i , Y_i , Y, J_i , J, V_i , V, Q_S , Q, T_V , r_i , R_i , W_{Ri} , D_{Ni} , D_{Fi} , T_{Ni} , T_{Fi} , θ , Q_{Si} , Q_U , GRF_{Ni} , GRF_{Fi} . We normalise P_j at unity and set θ 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 Y_{ji} , T_{ji} , L_{NUi} , L_{FUi} , L_{FSi} , L_{Si} , W_{Si} , r_i , R_i , W_{Ri} , GC_i , GRH_i , GRF_{ji} together 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 Y_{ji} , T_{ji} , L_{NUi} , L_{FUi} , L_{FSi} , L_{Si} , W_{Si} , r_i , R_i , W_{Ri} , GC_i , GRH_i , GRF_{ji} . 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.

We also used two sectors, formal and informal, which we defined as follows:

- Informal: Primary, Construction, Transport, Storage and Post, Wholesale and Retail, Hotels and Catering
- Formal: all other industries

For each region we use data averaged over the six-year period 2008-2013 to avoid cyclical influences on the share parameters. All the data come from *China Statistics Year Book* (SSB, various issues).

The effect of increasing the retirement age by one year depends not only on the values of the r_i (the proportion of the skilled labour which is retired in region *i*) but also on the age structure of the retired population. In fact, it depends on the proportion of the skilled labour force which is at retirement age. For retirement age of 60, using *t* as age (in years), we have:

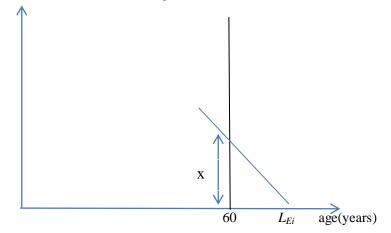
$$r_i = \mathop{\mathsf{a}}_{t=60}^{*} L_{Sit} / \mathop{\mathsf{a}}_{t=1}^{*} L_{Sit}$$

Changing retirement age from 60 to 61:

$$Dr_{i} = L_{Si60} / \overset{*}{\underset{t=1}{a}} L_{Sit} = (L_{Si60} / \overset{*}{\underset{t=60}{a}} L_{Sit})r_{i}$$
$$Dr_{i} / r_{i} = (L_{Si60} / \overset{*}{\underset{t=60}{a}} L_{Sit})$$

So we need the proportion of the retired population which is at retirement age. But we don't have data by region on L_{Sit} for each *i* and *t*. However, if we assume linear decline in distribution of population by age after 60, the size of the skilled labour force which is over aged 60 is given by $(1/2)(L_{Ei} - 60)L_{si60}$, where L_{Ei} is life expectancy. So the proportional change in r_i is $2/(L_{Ei} - 60)$. We can get this from the diagram below as well.

proportion of skilled labour force (region *i*)



The right-hand part of the age distribution of the population of skilled workers is drawn in the diagram. So x is the proportion of the skilled labour force aged 60 (assuming a discrete distribution). The implication for the proportional change in r_i is that it is $2/(L_{Ei} - 60)$. This follows from the fact that the proportional change in r_i at age 60 is simply x divided

by the area of the triangle which is x divided by $[(1/2)x(L_E - 60)]$ which is $2/(L_E - 60)$. This is consistent with the results from the formula above. So, the proportional change in the retirement ratio for a one-year delay of retirement is inversely proportional to life expectancy.

The life expectancy of the Chinese provinces in *China Statistical Year Book 2013* shows that the average of life expectancy in the coast is about 77.1 while in the interior about 73.5 so the appropriate shocks (the proportional change in r_i) is about 0.1170 for the coast and 0.1481 for the interior.

Variables	Simulat		Simulat		Simula		Simulation 4:	
	GRH end	•	Equal s		GRF end		<i>R</i> endog	,
	SR	LR	SR	LR	SR	LR	SR	LR
VUI	1.6435	1.6555	1.5918	1.5823	1.3018	1.2868	2.0377	2.2356
v_{UC}	1.0658	1.0838	1.1332	1.1189	1.0126	0.9973	2.1193	2.2527
V _{SI}	0.6280	0.7249	0.5225	0.4457	1.7345	1.6037	1.2758	2.0288
v_{SC}	0.2985	0.1614	0.3785	0.4872	1.3003	1.4860	0.2975	-0.8176
C _{NUI}	0.3794	0.3911	0.4010	0.3918	1.6863	1.6829	1.0135	1.1410
c_{NUC}	0.4379	0.4428	0.4474	0.4435	1.3953	1.3919	1.2410	1.2918
c_{FUI}	0.8276	0.8508	0.8707	0.8522	1.1496	1.1287	2.2291	2.4821
c_{FUC}	0.8860	0.9025	0.9170	0.9039	0.8586	0.8378	2.4566	2.6329
C _{NSI}	-0.0267	0.0668	-0.1192	-0.1933	2.1239	2.0022	0.3483	1.0331
C _{NSC}	-0.0964	-0.2441	-0.0430	0.0741	1.6589	1.8580	-0.5295	-1.7381
C _{FSI}	0.4215	0.5265	0.3505	0.2672	1.5873	1.4481	1.5639	2.3742
c_{FSC}	0.3517	0.2157	0.4267	0.5346	1.1223	1.3039	0.6861	-0.3970
gh_I	14.2800	14.1884	13.0524	13.1251	1.1847	1.1785	4.3415	4.3083
gh_C	10.4619	10.6279	11.8098	11.6782	0.8012	0.7971	2.9362	2.9138
jui	0.0203	0.0232	0.0255	0.0232	0.0216	0.0194	0.0358	0.0678
juc	0.0788	0.0749	0.0718	0.0750	-0.2695	-0.2715	0.2633	0.2186
jsı	-0.3858	-0.3011	-0.4947	-0.5618	0.4592	0.3388	-0.6294	-0.0401
jsc	-0.4322	-0.5880	-0.3941	-0.2704	-0.0337	0.1657	-1.4440	-2.7415
πh_{UI}	0.1074	0.1226	0.1348	0.1227	0.1139	0.1027	0.1889	0.3579
πh_{UC}	0.1625	0.1544	0.1482	0.1546	-0.5558	-0.5601	0.5432	0.4509
πh_{SI}	-0.4103	-0.3380	-0.5487	-0.6060	0.4280	0.3214	-0.5656	-0.1251
πh_{SC}	-0.4541	-0.6054	-0.4031	-0.2830	0.0457	0.2418	-1.5675	-2.8078
p_N	0.0402	0.0417	0.0429	0.0417	-2.1428	-2.1571	0.1053	0.1216
p_F	-0.9783	-1.0031	-1.0245	-1.0048	-0.9232	-0.8977	-2.6575	-2.9264
У _{NI}	0.1408	0.1460	0.1503	0.1462	3.1976	3.2530	0.3690	0.4262
УNC	0.0294	0.0305	0.0314	0.0306	0.3977	0.3415	0.0772	0.0892
y _{FI}	0.5680	0.5160	0.4758	0.5171	1.3512	1.4284	2.0919	1.5044
<i>YFC</i>	0.5242	0.5777	0.6214	0.5790	0.9689	0.8868	1.0899	1.6844
WSI	-2.7681	-2.6697	-2.5969	-2.6749	-1.9527	-2.0871	-8.9110	-7.7861
W _{SC}	-2.5105	-2.6697	-2.8012	-2.6749	-2.2871	-2.0871	-6.0250	-7.7861
π_{NI}	0.1809	0.1877	0.1932	0.1879	1.0547	1.0959	0.4743	0.5478
π_{NC}	0.0696	0.0722	0.0743	0.0723	-1.7451	-1.8156	0.1825	0.2108
π_{FI}	-0.4103	-0.4872	-0.5487	-0.4877	0.4280	0.5307	-0.5656	-1.4220
π_{FC}	-0.4541	-0.4254	-0.4031	-0.4258	0.0457	-0.0109	-1.5675	-1.2420
l _{FSI}	2.3578	2.1826	2.0483	2.1872	2.3807	2.6177	8.3454	6.3640
l_{FSC}	2.0564	2.2443	2.3981	2.2491	2.3328	2.0762	4.4575	6.5441
	2.4513	2.3903	2.4271	2.4754	2.5385	2.6385	7.3038	6.7118
l _{GCSC}	2.3471	2.4211	2.3443	2.2855	1.2049	1.0580	6.8993	7.5127
l _{GRSI}	18.4737	18.3086	16.7140	16.8449	18.3432	18.5827	0.1014	-0.2008
l_{GRSC}	8.8575	9.0549	10.1349	9.9784	8.4683	8.1868	-0.1236	0.2449

Appendix 4: Full Simulation Results

Variablas	Simula		Simula	tion 2:	Simula	tion 3:	Simula	Simulation 4:	
Variables	GRH end	ogenous	Equal s	hocks	GRF end	ogenous	R endog	genous	
	SR	LR	SR	LR	SR	LR	SR	LR	
l _{SI}	6.1828	6.0337	5.5900	5.7083	6.1828	6.3921	6.1828	4.8858	
l_{SC}	3.6299	3.8099	4.1542	4.0114	3.6299	3.3772	3.6299	5.1957	
l_{NUI}	0.1809	0.1877	0.1932	0.1879	1.0547	1.0959	0.4743	0.5478	
l_{FUI}	-0.4103	-0.4872	-0.5487	-0.4877	0.4280	0.5307	-0.5656	-1.4220	
l_{NUC}	0.0696	0.0722	0.0743	0.0723	-1.7451	-1.8156	0.1825	0.2108	
l_{FUC}	-0.4541	-0.4254	-0.4031	-0.4258	0.0457	-0.0109	-1.5675	-1.2420	
l_{UI}	0.0735	0.0651	0.0584	0.0651	0.9409	0.9932	0.2853	0.1900	
l_{UC}	-0.0929	-0.0822	-0.0739	-0.0823	-1.1893	-1.2555	-0.3607	-0.2401	
q_{UI}	0.0735	0.0651	0.0584	0.0651	0.9409	0.9932	0.2853	0.1900	
q_{UC}	-0.0929	-0.0822	-0.0739	-0.0823	-1.1893	-1.2555	-0.3607	-0.2401	
q_{SI}	0.0000	-0.1491	0.0000	0.1183	0.0000	0.2093	0.0000	-1.2970	
q_{SC}	0.0000	0.1800	0.0000	-0.1428	0.0000	-0.2526	0.0000	1.5659	
q_I	0.0465	-0.0137	0.0369	0.0847	0.5947	0.7048	0.1804	-0.3572	
q_C	-0.0577	0.0171	-0.0459	-0.1052	-0.7389	-0.8757	-0.2241	0.4438	
p _{GCI}	-2.7681	-2.6697	-2.5969	-2.6749	-1.9527	-2.0871	-8.9110	-7.7861	
<i>p_{GCC}</i>	-2.5105	-2.6697	-2.8012	-2.6749	-2.2871	-2.0871	-6.0250	-7.7861	
p _{GRI}	-2.7681	-2.6697	-2.5969	-2.6749	-1.9527	-2.0871	-8.9110	-7.7861	
<i>p_{GRC}</i>	-2.5105	-2.6697	-2.8012	-2.6749	-2.2871	-2.0871	-6.0250	-7.7861	
gc_I	2.4048	2.4040	2.3902	2.3908	1.9438	1.9337	7.1234	7.0689	
gc _C	2.4048	2.4040	2.3902	2.3908	1.9438	1.9337	7.1234	7.0689	
grh _I	32.8121	32.5787	29.6917	29.8768	0.0000	0.0000	0.0000	0.0000	
grh_C	16.1119	16.3948	18.4154	18.1910	0.0000	0.0000	0.0000	0.0000	
<i>y</i> _I	-0.2053	-0.2531	-0.2914	-0.2534	0.6453	0.7267	-0.2050	-0.7389	
Ус	-0.2997	-0.2787	-0.2624	-0.2790	-0.4822	-0.5429	-1.0517	-0.8137	
у	-0.2610	-0.2682	-0.2742	-0.2685	-0.0206	-0.0232	-0.7051	-0.7831	
j _I	-0.2580	-0.2409	-0.3214	-0.3350	0.0473	0.0121	-0.4645	-0.4006	
jc	-0.2388	-0.2951	-0.2210	-0.1763	0.2428	0.3216	-0.7830	-1.2450	
j	-0.2610	-0.2682	-0.2742	-0.2685	-0.0206	-0.0232	-0.7051	-0.7831	
v_I	1.4870	1.5413	1.4231	1.3800	1.5624	1.4966	1.9661	2.4972	
v _C	0.9265	0.8825	1.0001	1.0350	0.7902	0.8478	1.7571	1.3735	
v	1.3077	1.3143	1.2883	1.2830	1.4419	1.4442	1.9381	2.0304	
r_{I}^{*}	-14.8100	-14.8100	-13.3900	-13.3900	-14.8100	-14.8100	-14.8100	-14.8100	
r_{C}^{*}	-11.7000	-11.7000	-13.3900	-13.3900	-11.7000	-11.7000	-11.7000	-11.7000	
r_I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-27.4072	-25.7358	
r_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-22.9259	-26.3574	

Appendix 4: Full Simulation Results (continued)

Notes: lower-case letters represent the proportional changes (log differential) of their upper-case counterparts. "SR" and "LR" are abbreviations of "short run" and "long run". The shock is set to - 0.1481 for r_I and -0.1170 to r_C .

Variables	Simulatio GRH endog		Simulatio GRF endog		Simulation 4: <i>R</i> endogenous		
_	SR	LR	SR	LR	SR	LR	
VUI	6.7829	6.8155	5.3612	5.2896	8.4940	9.2476	
v _{UC}	4.4792	4.5280	4.2047	4.1319	8.8110	9.3189	
v _{SI}	2.5233	2.7869	7.0663	6.4417	5.1200	7.9866	
v _{sc}	1.3032	0.9304	5.4783	6.3648	1.3674	-2.8778	
C _{NUI}	1.5927	1.6245	6.9200	6.9038	4.2348	4.7201	
C _{NUC}	1.8257	1.8390	5.7616	5.7455	5.1508	5.3440	
C _{FUI}	3.4706	3.5339	4.7367	4.6369	9.3052	10.2683	
C _{FUC}	3.7036	3.7484	3.5782	3.4786	10.2212	10.8923	
C _{NSI}	-0.1846	0.0697	8.6474	8.0664	1.2507	3.8576	
C _{NSC}	-0.3577	-0.7593	6.9382	7.8887	-2.0800	-6.6809	
C _{FSI}	1.6933	1.9791	6.4640	5.7995	6.3211	9.4058	
C _{FSC}	1.5202	1.1501	4.7548	5.6218	2.9905	-1.1326	
gh _I	58.3129	58.0637	4.9551	4.9258	17.9327	17.8064	
gh_C	44.5159	44.9675	3.3513	3.3314	12.1284	12.0430	
jui	0.0886	0.0964	0.0831	0.0730	0.1585	0.2803	
juc	0.3216	0.3110	-1.0754	-1.0853	1.0745	0.9042	
jsı	-1.6887	-1.4584	1.8104	1.2356	-2.8256	-0.5822	
jsc –	-1.7641	-2.1880	-0.0124	0.9399	-5.8925	-10.8321	
πh_{UI}	0.4679	0.5092	0.4389	0.3855	0.8372	1.4805	
πh_{UC}	0.6634	0.6414	-2.2182	-2.2387	2.2164	1.8652	
πh_{SI}	-1.8141	-1.6175	1.6771	1.1684	-2.6222	-0.9451	
πh_{SC}	-1.8447	-2.2565	0.3100	1.2458	-6.3770	-11.0986	
p_N	0.1690	0.1730	-8.7821	-8.8504	0.4410	0.5032	
p_F	-4.0990	-4.1665	-3.8200	-3.6984	-11.0827	-12.1065	
<i>Y_{NI}</i>	0.5921	0.6063	12.8749	13.1398	1.5452	1.7631	
Улс	0.1238	0.1268	1.9451	1.6769	0.3232	0.3688	
<i>Y</i> _{FI}	2.2849	2.1434	5.4971	5.8658	8.4605	6.2240	
<i>Y_{FC}</i>	2.2543	2.3998	4.1299	3.7380	4.7057	6.9689	
WSI	-11.3568	-11.0894	-8.0081	-8.6497	-36.4945	-32.2121	
WSC	-10.6563	-11.0894	-9.6046	-8.6497	-25.5080	-32.2121	
π_{NI}	0.7611	0.7794	4.0928	4.2894	1.9861	2.2662	
π_{NC}	0.2928	0.2999	-6.8370	-7.1735	0.7641	0.8719	
π_{FI}	-1.8141	-2.0232	1.6771	2.1675	-2.6222	-5.8825	
π_{FC}	-1.8447	-1.7667	0.3100	0.0397	-6.3770	-5.1376	
l _{FSI}	9.5427	9.0662	9.6852	10.8171	33.8724	26.3296	
l _{FSC}	8.8115	9.3227	9.9146	8.6893	19.1311	27.0745	
l _{GCSI}	10.1588	9.9929	10.4397	10.9172	30.1500	27.8964	
l _{GCSC}	9.7432	9.9446	5.2606	4.5595	28.5216	30.8568	
l _{GRSI}	75.3010	74.8521	74.7186	75.8621	0.4083	-0.7422	
l _{GRSC}	37.7979	38.3349	36.2153	34.8711	-0.4978	0.9050	

Appendix 5: Simulation Results of Increase of Retirement Age from 60 to 65

Variables	Simulatio		Simulati		Simulati		
v ariables	GRH endog		GRF endo		<i>R</i> endogenous		
	SR	LR	SR	LR	SR	LR	
l _{SI}	25.1988	24.7931	25.1988	26.1978	25.1988	20.2614	
l_{SC}	15.4906	15.9803	15.4906	14.2844	15.4906	21.4516	
l _{NUI}	0.7611	0.7794	4.0928	4.2894	1.9861	2.2662	
l_{FUI}	-1.8141	-2.0232	1.6771	2.1675	-2.6222	-5.8825	
l_{NUC}	0.2928	0.2999	-6.8370	-7.1735	0.7641	0.8719	
l_{FUC}	-1.8447	-1.7667	0.3100	0.0397	-6.3770	-5.1376	
l_{UI}	0.2932	0.2702	3.6539	3.9039	1.1489	0.7858	
l_{UC}	-0.3706	-0.3416	-4.6188	-4.9347	-1.4523	-0.9933	
q_{UI}	0.2932	0.2702	3.6539	3.9039	1.1489	0.7858	
q_{UC}	-0.3706	-0.3416	-4.6188	-4.9347	-1.4523	-0.9933	
q_{SI}	0.0000	-0.4056	0.0000	0.9991	0.0000	-4.9374	
q_{SC}	0.0000	0.4897	0.0000	-1.2062	0.0000	5.9610	
q_I	0.1853	0.0215	2.3094	2.8350	0.7261	-1.3201	
q_C	-0.2303	-0.0267	-2.8696	-3.5227	-0.9023	1.6403	
Рдсі	-11.3568	-11.0894	-8.0081	-8.6497	-36.4945	-32.2121	
PGCC	-10.6563	-11.0894	-9.6046	-8.6497	-25.5080	-32.2121	
<i>P_{GRI}</i>	-11.3568	-11.0894	-8.0081	-8.6497	-36.4945	-32.2121	
<i>P</i> _{GRC}	-10.6563	-11.0894	-9.6046	-8.6497	-25.5080	-32.2121	
gc_I	9.9735	9.9714	8.1302	8.0822	29.4239	29.2165	
gc _C	9.9735	9.9714	8.1302	8.0822	29.4239	29.2165	
grh _I	133.7502	133.1154	0.0000	0.0000	0.0000	0.0000	
grh_C	68.7388	69.5085	0.0000	0.0000	0.0000	0.0000	
<i>y</i> _I	-0.9210	-1.0512	2.5149	2.9034	-1.0240	-3.0565	
УС	-1.2146	-1.1575	-1.7968	-2.0866	-4.2719	-3.3661	
у	-1.0944	-1.1140	-0.0317	-0.0439	-2.9423	-3.2394	
j _I	-1.1220	-1.0753	0.2008	0.0324	-2.0506	-1.8075	
jс	-0.9774	-1.1305	1.0139	1.3897	-3.2010	-4.9599	
j	-1.0944	-1.1140	-0.0317	-0.0439	-2.9423	-3.2394	
VI	6.1231	6.2710	6.3771	6.0629	8.1542	10.1759	
V _C	3.9057	3.7861	3.3654	3.6404	7.3359	5.8758	
v	5.4142	5.4322	5.9047	5.9159	8.0493	8.4008	
r* ₁	-60.3600	-60.3600	-60.3600	-60.3600	-60.3600	-60.3600	
r_{C}^{*}	-49.9300	-49.9300	-49.9300	-49.9300	-49.9300	-49.9300	
r _I	0.0000	0.0000	0.0000	0.0000	-111.7398	-105.3768	
r _C	0.0000	0.0000	0.0000	0.0000	-97.7475	-110.8109	

Appendix 5: Simulation Results of Increase of Retirement Age from 60 to 65 (continued)

Notes: lower-case letters represent the proportional changes (log differential) of their upper-case counterparts. "SR" and "LR" are abbreviations of "short run" and "long run". The shock is set to - 0.6036 for r_I and -0.4993 to r_C .