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Prospects of interventions to alleviate rural–urban migration in Jiangsu Province, China based on sensitivity and scenario analysis

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ABSTRACT

Rural–urban migration is an adaptive response to location-specific environmental or socio-economic stressors. Jiangsu Province, China is witnessing rapid economic growth fuelled by manufacturing and services sector. Rural–urban migration in Jiangsu, which brings higher stress to resource-carrying capacity of urban areas, is driven by rural "push" factors, principally labour surplus and unemployment in agriculture. This study investigates possible policy interventions aimed at relieving the rapid rural–urban migration in Jiangsu based on a sensitivity analysis of driving factors in rural agricultural production. It shows that rural–urban migration is sensitive to input elasticities of precipitation and labour. Two groups of scenario analysis corresponding to possible policy interventions are implemented. The first policy focuses on providing government subsidies to rural non-agricultural industries then compensate for the shrinking agricultural production. Another policy supports education in rural areas to provide more skilled labour resource which can be absorbed by non-agricultural industries. Both two policies are effective in reducing rural unemployment and alleviating rural–urban migration.

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1 Introduction

Migration is a human response to uneven spatial distribution of population under changing natural environment or developing socio-economy (McLeman and Smit 2006). Migration can be driven by multiple factors. Food and Agricultural Organization of the United Nations (FAO) has identified five main drivers: (a) income differences, poverty and food security; (b) lack of education, family reunification and social networks; (c) demographic asymmetries, rural youth and gender inequalities; (d) environmental factors; and (e) conflicts, political instability and protracted crises (Wrathall *et al.* 2018). The migration pattern of different groups of people exposed to similar external stresses can also be different (Curran 2002, Henry *et al.* 2004).

Du *et al.* (2005) found that poor population migrated more often if they are financially able to. By migrating to new locations, migrants are able to earn better livelihood but may cause shortage of common pool resources or even conflicts with local residents (Li 2005, Li and Pan 2010). Black *et al.* (2011) stressed that the effect of environmental change on the decision to migrate is embedded in multiple factors including politics, economy, society and demographic conditions. In this context, Chen *et al.* (2014) associated rural mobility patterns with three categories of societies: pre-modern traditional society, transitional society, and advanced society. These correspond to three stages of land use patterns: subsistence, intensifying, and intensive respectively. In terms of agriculture, Cattaneo and Peri (2016) found that variability and extremes in surface temperatures can drive migration from dryland areas by adversely affecting agricultural production. Reduction or failure in crop cultivation brings increasing amount of migration from agricultural-dependent areas to other regions (Henry *et al.* 2004, Gray and Mueller 2012, Cai *et al.* 2016, Wrathall *et al.* 2018).

A variety of policy interventions to resolve regional migration stress have been proposed based on their respective interpretations of what drives migration. One option that has been proposed is to create jobs in industries and services sectors while at the same time reducing the gap between rural and urban personal incomes (Zhang and Song 2003, Long and Woods 2011, Long *et al.* 2012). Scheffran *et al.* (2012), however, emphasized that adaptation strategies should be delinked from measures to stop migration. Instead, adaptation options aimed at preserving and improving livelihoods of young people should be developed and implemented to decrease the pressure on them to migrate. Warner (2010) recommended improving the education and training that facilitate access of rural communities affected by environmental change to alternative non-agriculture-based livelihoods. Technical measures that complement better resource and land management alongside improved access to risk management tools such as risk sharing and risk transfer tools like (micro) insurance can also be implemented. The importance of people being actively involved in planning activities and as much as possible be given the freedom to move and react to micro-level incentive structures has also been highlighted (Davidson 2009). Long *et al.* (2010) pointed out the responsibility of government to lay out plans and provide infrastructure and public services, together with the participation of

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farmers in the planning and decision-making process themselves. For example, China's policies on rural out-migration should include restricting frontier clearing through land zoning and other ecological-protection policies. Non-migrants should be encouraged to adjust their agricultural land holdings, and their interests should be protected through subsidizing agricultural land, and improving rural infrastructure and farmers' living conditions (Chen *et al.* 2014). Here, contemporary European and North American rural restructuring can shed light on sustainable rural development in China, such as the rural community regeneration (Long and Woods 2011), multifunctional land use (Wilson 2010) and community supported agriculture (CSA) (Lamb 1994). Others have advised reducing migration stress either by adapting interventions to better manage large migratory movements or intensive investment in interventions. For example, investment in rural agricultural infrastructure can ameliorate water stress-induced migration or water stress altogether and as a result slowdown rapid, sprawling and uncontrolled urbanization (Moench 2002; Nawrotzki *et al.* 2017, Wrathall *et al.* 2018).

As in any other fast-evolving economy, rural–urban migration is extensively occurring in Jiangsu province, China, where a record 21.6% of the rural-registered population migrated to urban areas in Jiangsu in 2005 and 2006. Most of the migrants originated from rural northern Jiangsu and relocated to the more urbanized southern parts of the province (Huang 2006, Chen 2007, Zhang and Huang 2009, Wang 2017). According to a rural–urban migration model recently developed by Lyu *et al.* (2019), migration in Jiangsu province appears to occur two to four years after changes of rural employment and is being driven by underemployment in rural areas, possibly due to structural transformation of Chinese economy away from the agricultural sector (FAO 2018). The motivation of this study is to inspire possible policy interventions based on such insights to relieve the stress of regional rural–urban migration of the province such that it is transferrable to other regions with similar drivers of rural–urban migration.

The design of interventions is inspired by the sensitive driving factors behind rural–urban migration in the province. The rural–urban migration model that has successfully interpreted the migration in the province (Lyu *et al.* 2019) is used to simulate rural–urban migration as a function of rural unemployment, which in turn is estimated based on an economic model of agricultural production. A Sobol-based sensitivity index (Van Emmerik *et al.* 2014) is then used to assess the sensitivity of migration to the inputs of agricultural production, such as labour and rainfall. Two groups of scenario analysis are designed based on the sensitivity analysis. One of the scenario analysis is based on government subsidies for non-agricultural sectors and the other is based on investments towards rural education, both effectively targeting rural employment (Perry and Harmon 1992, Fan *et al.* 2004, Zhang and Fan 2004, Wei 2006).

This paper is divided into four sections. Section 2 introduces the method implemented in this research, including the Cobb-Douglas-based production function for rural non-agricultural sectors, the rural–urban migration model, and the Sobol-based sensitivity analysis approach. The results of sensitivity and scenario analysis are shown in section 3. Section 4 discusses the results.

2 Methodology

2.1 Study area

As shown in Figure 1, Jiangsu Province is located on the east coast of China. The province has one of the highest population densities in China and urbanization is rapid. Rural agricultural production has shrunk over many years (Bureau of Statistics of Jiangsu 1987–2016) leading to a significant amount of surplus rural labour. The underemployed agricultural labour forms the main driver of rural–urban net migration in Jiangsu (Lyu *et al.* 2019) and is being absorbed by newly developed modern industries in urban areas.

2.2 Cobb-Douglas production function

The Cobb-Douglas production function (Cobb and Douglas 1928) has been applied to describe the evolution of labour demand in rural agricultural and non-agricultural sectors. The original form of Cobb-Douglas production function is:

$$Y_j = A_j K_j^{\alpha} L_j^{\beta} \tag{1}$$

where Y_j is the total output of industry j; A_j is the Total Factor Productivity (TFP) of industry j; K_j is capital input of industry j; L_j is labour input of industry j. Also, α and β are output elasticities of capital and labour, which are in the form of exponential weights such that $\alpha + \beta = 1$.

A more generalized form of Cobb-Douglas production function (Lyu *et al.* 2019) has been applied to describe the multiple-factor-driven process of production:

$$Y_j = A_j \prod\nolimits_{i=1}^{n} F_{ji}^{\alpha_i} \tag{2}$$

where n driving factors $F_{j1}, ..F_{ji}, ..F_{jn}$ (including labour) and associated elasticities $\alpha_1, .., \alpha_i, .., \alpha_n$ has been considered as multiple inputs.

For a_i, we have:

$$\sum\nolimits_{i=1}^{n} \alpha_i = 1 \tag{3}$$

We set "Labour" F_{jn} as L_j with α_n, then Equation (2) turns into the form:

$$Y_j = A_j \prod\nolimits_{i=1}^{n-1} F_{ji}^{\alpha_i} L_j^{\alpha_n} \tag{4}$$

with

$$\alpha_n = 1 - \sum\nolimits_{i=1}^{n-1} \alpha_i \tag{5}$$

It is assumed that the resources are allocated in an efficient and competitive manner. Therefore, labour wage is set equal to the marginal value of labour, and then assumed to be equal to income per unit labour.

$$w_j = \frac{\partial Y_j}{\partial L_j} = \left(1 - \sum\nolimits_{i=1}^{n-1} \alpha_i\right) \frac{A_j \prod_{i=1}^{n-1} F_{ji}^{\alpha_i}}{L_j^{\sum_{i=1}^{n-1} \alpha_i}} \tag{6}$$

Lyu *et al.* (2019) show that the system dynamic equation corresponding to Equation (5) can be given as:

$$\frac{\dot{w}_j}{w_j} = \frac{\dot{A}_j}{A_j} + \sum_{i=1}^{n-1} \alpha_i \frac{\dot{F}_{ji}}{F_{ji}} - \frac{\dot{L}_j}{L_j} \sum_{i=1}^{n-1} \alpha_i \tag{7}$$

Since wage rate in the jth sector can be estimated as total income that is being generated in that sector, M_j, divided by the number of people employed, L_j, Lyu *et al.* (2019) have shown that Equation (7) can be written as:

$$\frac{\dot{L}_j}{L_j} = \frac{\frac{\dot{A}_j}{A_j} + \sum_{i=1}^{n-1} \alpha_i \frac{\dot{F}_{ji}}{F_{ji}} - \frac{\dot{M}_j}{M_j}}{\sum_{i=1}^{n-1} \alpha_i} \cdot \left(1 - \frac{1}{\sum_{i=1}^{n-1} \alpha_i}\right)^{-1} = -\left(\frac{\frac{\dot{A}_j}{A_j} + \sum_{i=1}^{n-1} \alpha_i \frac{\dot{F}_{ji}}{F_{ji}} - \frac{\dot{M}_j}{M_j}}{1 - \sum_{i=1}^{n-1} \alpha_i}\right) \tag{8}$$

This is a powerful representation of labour dynamics and employment especially because it is a function of variables recoverable from many national socio-economics statistical data bases and hence generalizable to other countries.

Since the production function is of Cobb Douglas form, it can be shown that total income generated, M_j, is attributable to a certain fraction of production, Y_j, given by

$$M_j = \alpha_n Y_j \tag{9}$$

where α_n is the elasticity of labour input to production.

2.3 Todaro-based rural–urban net migration model

A Todaro-based model for rural–urban net migration μ_{RU} has been applied to simulate the transfer of population from rural to urban areas (Lyu *et al.* 2019):

$$\frac{\mu_{RU}}{S_R} = F\left(\frac{\left(1 - U_U^\ell\right) Y_U^\ell - \left(1 - U_R^\ell\right) Y_R^\ell}{\left(1 - U_U^\ell\right) Y_U^\ell}\right) \tag{10}$$

where S_R is rural labour supply; $U_U(t)$, $U_R(t)$ are unemployment rates in the urban and rural area, respectively, that are based on labour dynamics modelled by Equation (8); $Y_U(t)$ is net urban real income; $Y_R(t)$ is net rural real income; and $F(\cdot)$ is an increasing function with $F\prime > 0$. We denote ℓ-year-lagged variables by superscript ℓ, for example, $U_U(t - \ell)$ is denoted by U_U^ℓ.

By multiplying S_R on both sides, we have

$$\mu_{RU} = \hat{F}\left(\frac{\left(1 - U_U^\ell\right) Y_U^\ell - \left(1 - U_R^\ell\right) Y_R^\ell}{\left(1 - U_U^\ell\right) Y_U^\ell}\right) = \hat{F}\left(\eta^\ell\right) \tag{11}$$

where superscript ℓ represent a lag of ℓ years and $\hat{F}(\cdot)$ is another increasing function as $S_R > 0$.

Under the assumptions that (a) the unemployment rate U_U is much less than U_R ($U_U \ll U_R$) and close to 0; and (b) the migration prospect of rural population is not sensitive to income difference between rural and urban areas; Equation (11) transforms to:

$$\mu_{RU} = \tilde{F}\left(U_R^\ell - U_U^\ell\right) \tag{12}$$

where $\tilde{F}(\cdot)$ is another increasing function. The above equations have been extensively described in Lyu *et al.* (2019).

2.4 A Sobol-based sensitivity analysis

A sensitivity analysis is carried out in order to capture most sensitive variables that bring significant changes to various intermediate or output variables of the migration model. The modelled labour demand, which is a fundamental variable of unemployment rate and rural–urban net migration flow, is expected to be sensitive to the parameters of the Cobb-Douglas production function (Equation (4)). These parameters, or elasticities, of the driving factors of productivity are used in the sensitivity analysis. A Sobol-based sensitivity index (Van Emmerik *et al.* 2014) was chosen to measure the sensitivity of modelled migration to different elasticities.

The sensitivity analysis is however complicated by the fact the sum of all the elasticities have to be equal to one owing to Cobb Douglas formulation of the production function. This means that the parameters on which sensitivity analysis is operated are linked together and cannot be tested separately. We therefore used a comparative method to test sensitivity of a pair of parameters at a time and average it over the pairs to obtain Sobol-based sensitivity index of a parameter. After a selection of two parameters to be perturbed, we record the sum of these two parameters, set the first parameter as "actively changing parameter", and perturb it by multiplying it by m values of factor φ evenly spaced between 0.5 and 1.5. The elasticity of the second parameter is then indirectly being perturbed, which we call "passively changed parameter". This perturbation is calculated by subtracting the perturbed elasticity of the actively changing parameter from the sum of the elasticities of the two parameters.

For each group of the selected parameter i and j, V_{ij} is the variance of m root mean square errors (RMSE) calculated by comparing the simulated series of rural–urban migration based on perturbed parameters with the series directly calculated with data obtained from the annual yearbooks. The latter is called observed rural–urban migration (see Lyu *et al.* 2019). We let values of multiplication factor φ to vary between 0.5 and 1.5 with a step size of 0.1. As a result, the number of RMSEs for every parameter pair (i,j), is m = 11.

Then we select a Sobol-based sensitivity index, which is calculated by:

$$\mathrm{E}_{ij} = \frac{V_{ij}}{\sum_{j=1}^{n} V_{ij}} \tag{13}$$

with n= 6 as the number of factors of production (inputs including labour, plant area, precipitation, machinery power, fertilizer, and pesticide (see Lyu *et al.* 2019) and $V_{ij} = 0$ for $i = j$.

For every selected pair of parameters i and j (where parameter i is actively changing), a value of E_{ij} is obtained. The number of different E_{ij} quantities is 30 in total because a pair (i, j) can be uniquely selected ${}_nP_2$ times (where P is the permutation operator). A higher value of E_{ij} indicates more significant influence of parameter change on the results of model calculation.

To reflect a comprehensive level of sensitivity for each parameter j, an average sensitivity index ($\bar{\mathrm{E}}$) is calculated as the average of pairwise sensitivity over all other parameters i:

$$\bar{\mathrm{E}}_j = \frac{\sum_{i=1}^{n} \mathrm{E}_{ij}}{n} \tag{14}$$

2.5 Scenario analysis of possible policy intervention

2.5.1 Direct subsidies on non-agricultural industries

A scenario analysis was carried out to test the impact of possible new government policy aimed at relieving the rural–urban net migration at the onset of a dry period by artificially increasing the income generates from non-agricultural sector in rural areas.

The migration model described by Equation (11) (Lyu *et al.* 2019) is used; it is driven by the labour dynamics shown in Equation (8). As can be seen from Equation (8), the rate of change in labour ($\frac{\dot{L}_j}{L_j}(t)$ responds positively a change in $\frac{\dot{M}_j}{M_j}$ of similar sign. This means that using Equation (8), one can evaluate the long-term effect on labour dynamics, rural unemployment and rural–urban migration when additional income is injected at any point in time through $\frac{\dot{M}_j}{M_j}$. Here M_j is not individual income but total income generated by the jth sector that is attributed to labour activities (see Equation (9). Therefore, if all other factors and inputs of non-agricultural production remain the same, any government initiative to increase M_j means Y_j is increased proportionately, i.e. increasing income-linked labour activities in the non-agricultural sector means that non-agricultural production is increased in rural areas.

Note that in Fig. 2, 1992–2000 was a drought period. A sustained boost in total income at the beginning of a drought period was tested to see how its impact cascaded through the labour dynamics, unemployment and hence rural–urban migration. For this total income growth rate for rural non-agricultural production $\gamma_{M_{\mathrm{RNA}}} = \dot{M}_{\mathrm{RNA}}/M_{\mathrm{RNA}}$ was incremented by 0% to 50% (in steps of 2%). In terms of interventions this means that certain sustained level of investments is implemented by the government that increased non-agricultural income over time. These can be policies to encourage higher

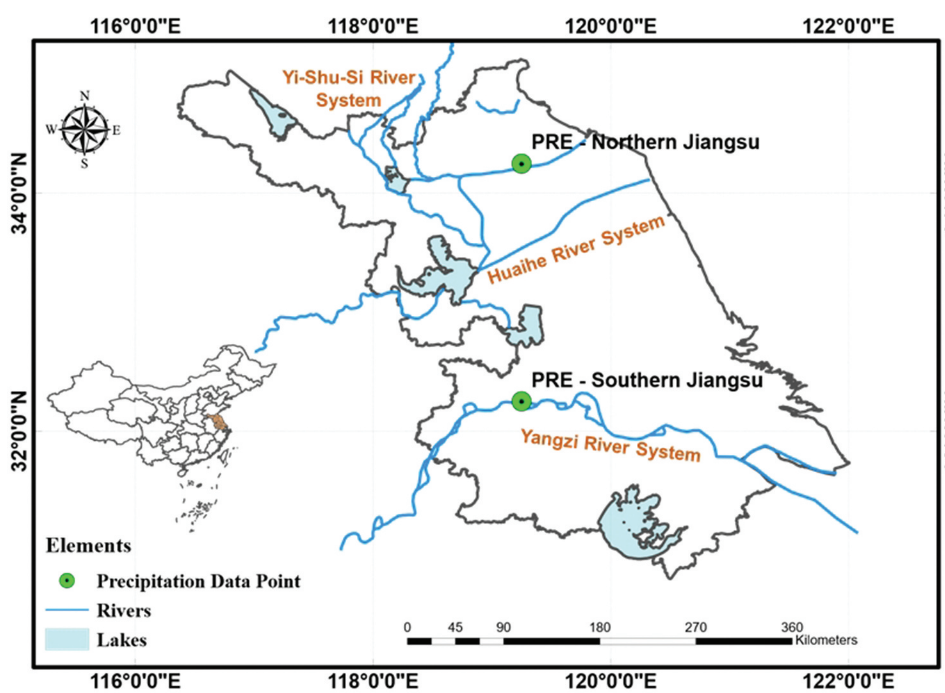

Figure 1. Map of Jiangsu Province, China.

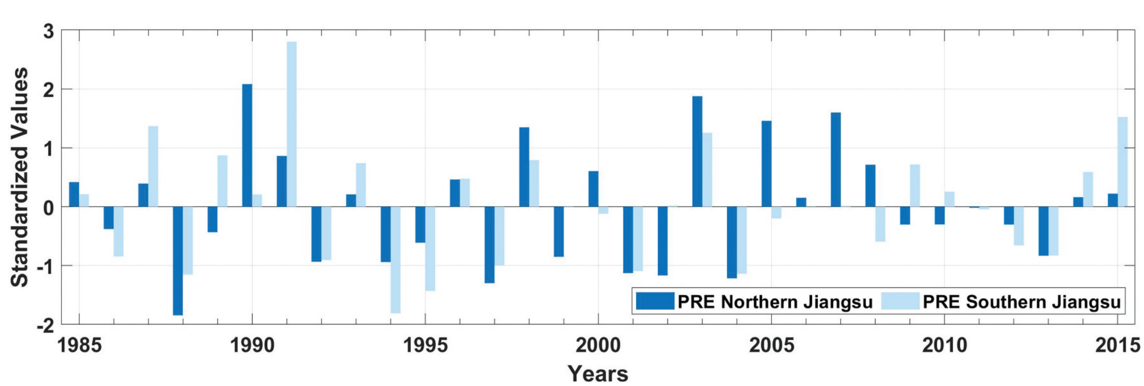

Figure 2. Standardized annual precipitation from the CRU database (CRU 1985-2015; Harris *et al.* 2014).

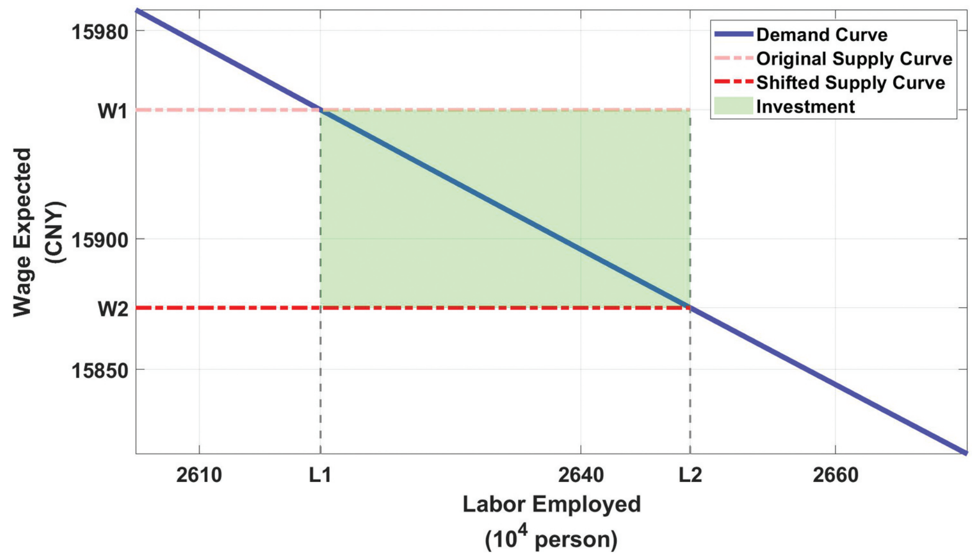

Figure 3. Illustration of labour demand and shifting supply so that more rural communities are employed. The green area shows the investment needed.

production of non-agricultural goods and services. Examples include the development of modern industrial sectors in rural areas, supporting the expansion of existing facilities or the establishment of new factories, or facilitating the flow of surplus agriculture labour flow into rural industrial production that leads to the corresponding increments in total income generated by the non-agricultural sector.

2.5.2 Investing on skills for non-agriculture labour market

The second scenario analysis relates to how much investment in educating rural people is needed so that they acquire skills useful for the rural non-agricultural sector and allow more households to enter the non-agricultural labour market. The supply function of labour can be interpreted as the output of labour delivered by households' profit maximization problem. More households entering the non-agricultural market then means that the costs for households to enter rural non-agricultural labour markets have been lowered. Such barriers to entry are often skills related, education costs for which is often high. The investment needed to subsidize these costs can be given by the product of any change in wages and the correspondingly additional labour employed.

To illustrate the needed investment, consider the example of non-agricultural labour demand that is constructed based on socio-economic data from the year 2013 in Fig. 3. A demand curve, here for labour, plots how wages in a competitive market vary with quantity of an input (labour) employed in a production activity (non-agricultural production). If more labour in rural non-agricultural sectors are to be competitively employed, i.e. the amount of employed labour increase from L_1 to L_2 (Fig. 3), then the average wage level would decrease from W_1 to W_2. Without influencing the production processes, e.g. through technological innovation, this would means lowering the supply function of labour. In other words, more households or individuals are encouraged (e.g. through skill development) to participate in the non-agricultural labour market and the investment needed from government agencies to facilitate this is indicated by $(W_2 - W_1)(L_2 - L_1)$.

3 Results and discussion

Lyu *et al.* (2019) estimated the function $\tilde{F}\left(\mathrm{U}_{\mathrm{R}}^{\ell} - \mathrm{U}_{\mathrm{U}}^{\ell}\right)$ in Equation (12), and found that a linear function was the best functional form for $\tilde{F}\left(\mathrm{U}_{\mathrm{R}}^{\ell} - \mathrm{U}_{\mathrm{U}}^{\ell}\right)$ with $\ell = 2$. This means that rural–urban net migration increases significantly by the change in rural–urban unemployment difference, lagged by two years. The elasticities used were from Sun *et al.* (2008), which are reported in second column of Table 1. Figure 4 shows the estimated migration model when compared with the observed rural–urban migration time series. All estimated parameters were significant at $p < 0.01$.

3.1 Sensitivity of parameters

The ranges of elasticities of actively changing parameters are shown in Table 1. Figure 5 plots the sensitivity indices for the modelled rural–urban net migration.

From Fig. 5, it can be observed that rural–urban net migration is most sensitive to precipitation elasticity, followed by labour, plant area and fertilizer application elasticities. This implies that rural to urban migration can partly be mitigated by making agriculture more climate resilient.

Note that this does not necessarily mean that climate is the cause of migration and that water availability for agriculture must be made more secure. Instead it means that measures should be taken so that migration is made less sensitive to water technology in agriculture. As rural–urban migration is mostly driven by rural underemployment in Jiangsu Province (Lyu *et al.* 2019), such measures could take form of either direct subsidies to artificially increase production by non-agricultural industries or to promote skills needed for non-agricultural production in rural areas. While the former would attract more expensive labour, the latter

Table 1. Ranges of actively changing parameters.

Elasticity	Value	Minimum	Maximum
Labour	0.534	0.267	0.801
Plant area	0.252	0.126	0.378
Precipitation	0.051	0.026	0.076
Fertilizer	0.090	0.045	0.135
Machinery	0.059	0.030	0.088
Pesticide	0.014	0.007	0.021

would mobilize more agricultural underemployed labour to the non-agricultural labour market in rural areas itself.

3.2 Policy interventions

3.2.1 Direct subsidies on non-agricultural industries

Figure 6(a) shows that rural unemployment rate starts to decline from 1992, with the shaded area showing the response space when $\gamma_{M_{\mathrm{RNA}}}$ (percentage change in rural non-agricultural growth rate) is varied between 0% and 50%.

Figure 6(b) shows how the new policy can reduce rural–urban migration. From 1994 to 2015, rural–urban net migration is reduced by implementing the new policy in 1992. We calculated the *changes* (both relative and absolute, accumulated over time) in rural personal net income Y_R, rural non-agricultural labour employed L_{RNA}, rural unemployment rate U_R and the amount of rural–urban migration μ_{RU} for each policy scenario (i.e. for $\gamma_{M_{\mathrm{RNA}}}$ ranging between 0% and 50%), implemented starting from 1992. These are shown in Tables 2 and 3.

Tables 2 and 3 show that a 1% increase in rural non-agricultural income growth rate would lead to a slight increase of 0.06% (154.51 CNY) in rural personal income. The improvement in rural non-agricultural employment is more significant, with 0.33% (1.21 million) more jobs provided, and

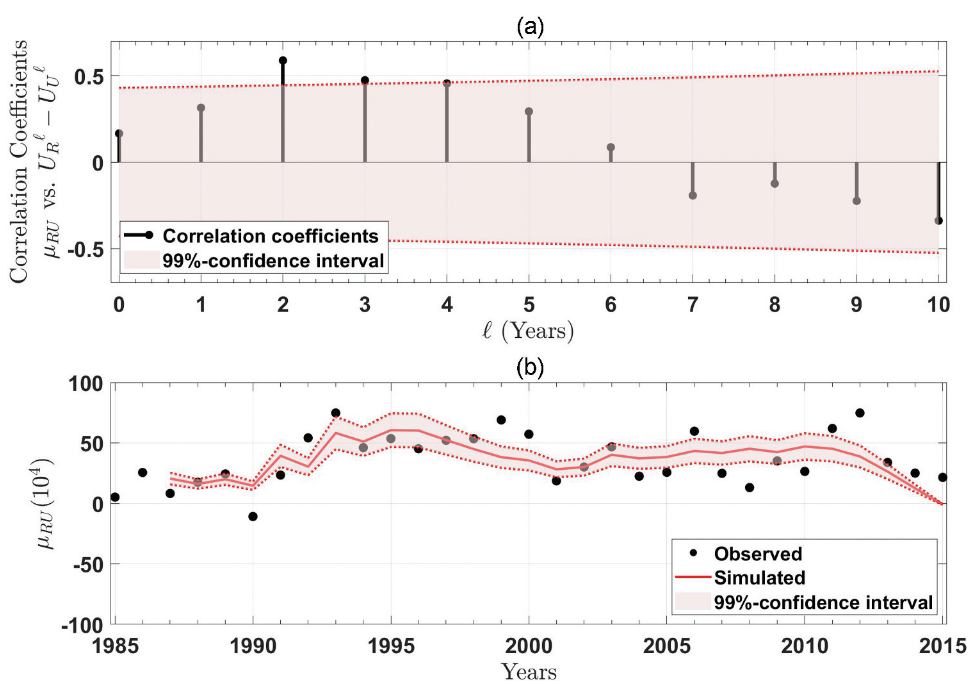

Figure 4. (a) Correlation coefficients between rural–urban net migration and rural–urban unemployment at different lags. (b) Unemployment-driven rural to urban net migration simulated with a 2-year lag. Shaded area shows 99% confidence interval. (Lyu *et al.* 2019).

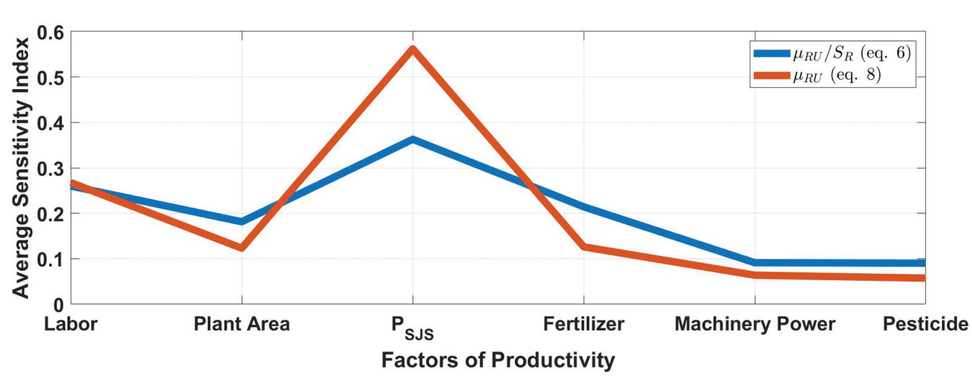

Figure 5. Sobol-based average sensitivity of rural–urban net migration to the elasticities of various inputs. Migration is most sensitive to precipitation elasticity, followed by labour, plant area and fertilizer application elasticities.

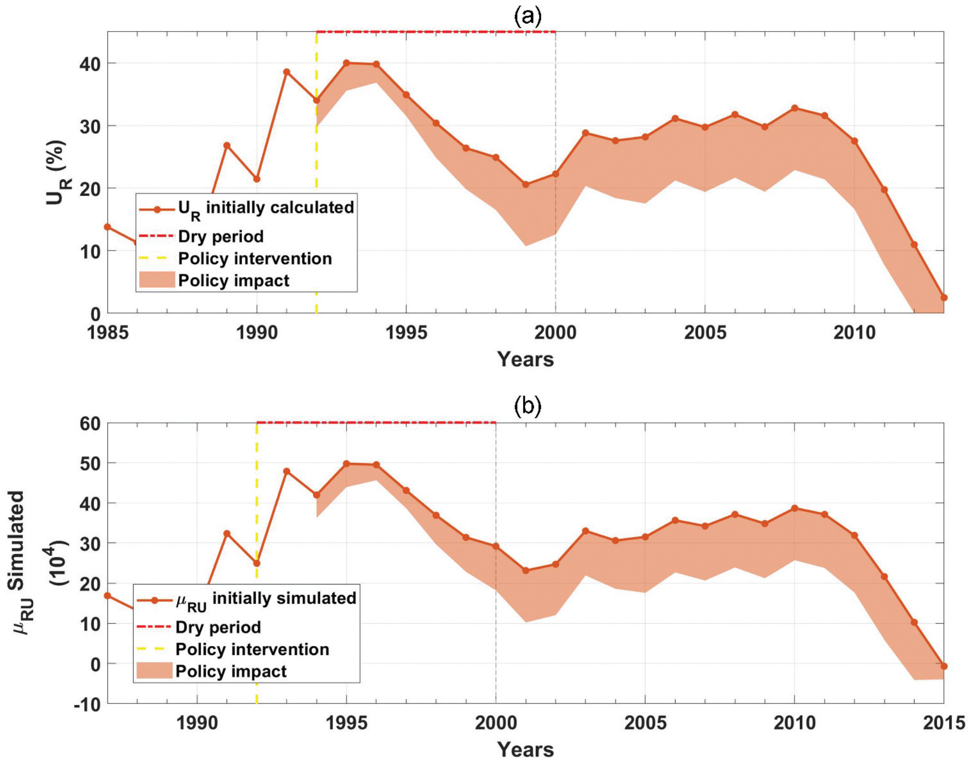

Figure 6. (a) Rural unemployment rate calculated under policy interventions of improving rural income at the beginning of a dry period (1992). (b) Rural–urban net migration simulated under the same policy interventions. Impacts of policy intervention on reduced rural unemployment and migration are evident.

Table 2. Relative accumulated changes in Y_R (rural personal income, 1992–2013), L_{RNA} (labour employed in rural non-agricultural sector, 1992–2013), U_R (unemployment rate, 1992–2013) and μ_{RU} (rural–urban migration, 1994–2015) when the growth rate of rural non-agricultural income ($\gamma_{M_{RNA}}$) is increased by 1% from 1992 onwards.

$\Delta Y_R/Y_R$	$\Delta L_{RNA}/L_{RNA}$	$\Delta U_R/U_R$	$\Delta\mu_{RU}/\mu_{RU}$
0.06%	0.33%	−0.26%	−0.27%

Table 3. Absolute accumulated changes in Y_R (1992–2013), L_{RNA} (1992–2013) and μ_{RU} (1994–2015) for 1% change in the growth rate of rural non-agricultural income ($\gamma_{M_{RNA}}$).

ΔY_R (CNY)	ΔL_{RNA} (10^4 capita)	$\Delta\mu_{RU}$ (10^4 capita)
154.51	120.66	−4.73

the unemployment rate in rural areas in Jiangsu will decline by about 0.26%. This would curb 0.27% (~47,300) of rural to urban migration.

In order to create the 50% of additional growth in non-agricultural income, the government would need to invest 4.328 billion CNY (US$621.50 million) in the province or approximately 0.41% of regional production of Jiangsu province (1045.641 billion CNY, with base year 2010). In 1992 alone, this additional growth in non-agricultural income will result in additional 1.407 million (16.70%) jobs created in the non-agriculture sector and migration reduced by 57,165 (~13.62%). The unemployment rate could reduce by 12.82%. Rural per capita income could increase by 7725.6 CNY even with increased rural employment in the scenario of a 50% increase of total income growth rate in the non-agriculture sector. The government policy interventions starting from 1992 has long-term impact on migration as it propagates through the economy and labour demand. Each percentage point increase in growth rate of non-agricultural income will reduce migration by a total of 47,340 over the period 1994–2015.

3.2.2 *Investing on skills for non-agriculture labour market*

Ten scenarios of absorbing 10% to 100% of "surplus" rural labour (i.e. unemployed labour) in the rural non-agricultural sectors from 1985–2013 were analysed, with results shown in Figs. 7 and 8. To absorb 10% to 100% of total rural unemployed, an average investment of 0.46 to 30.55 billion CNY (with base year 2010) would be needed for each year over the entire period. Figure 8 shows that accumulated investment for different percentages of unemployed absorbed.

4 Conclusions

Using a model based on a Cobb-Douglas-based production function and Todaro-based rural–urban net migration description, a Sobol-based sensitivity analysis and scenario analysis was carried out. This was undertaken to reveal the most sensitive driving factors of rural–urban migration and to guide possible policy interventions for ameliorating rural–urban migration.

The Sobol-based sensitivity analysis showed that migration was most sensitive to the elasticity of precipitation, implying that climate resilience is a key factor in agricultural production and the rural–urban migration in the

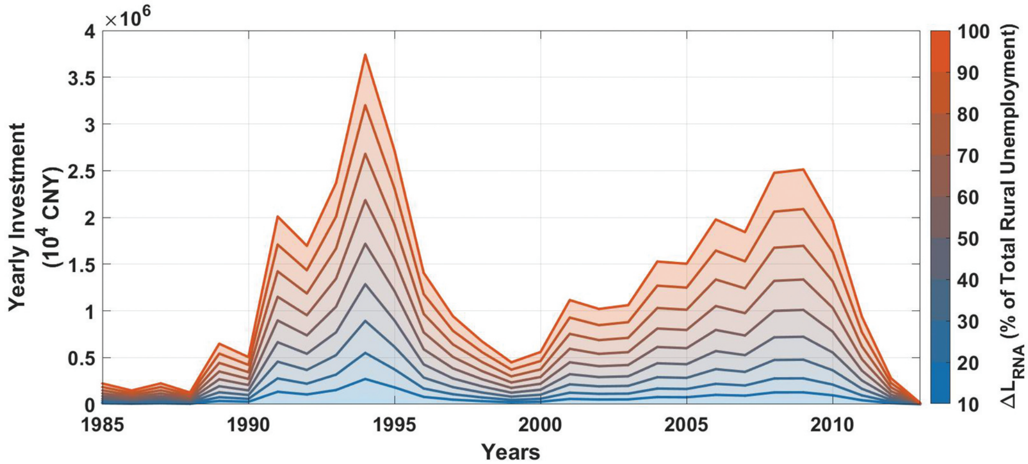

Figure 7. Annual investment required to employ labour in rural non-agricultural sectors.

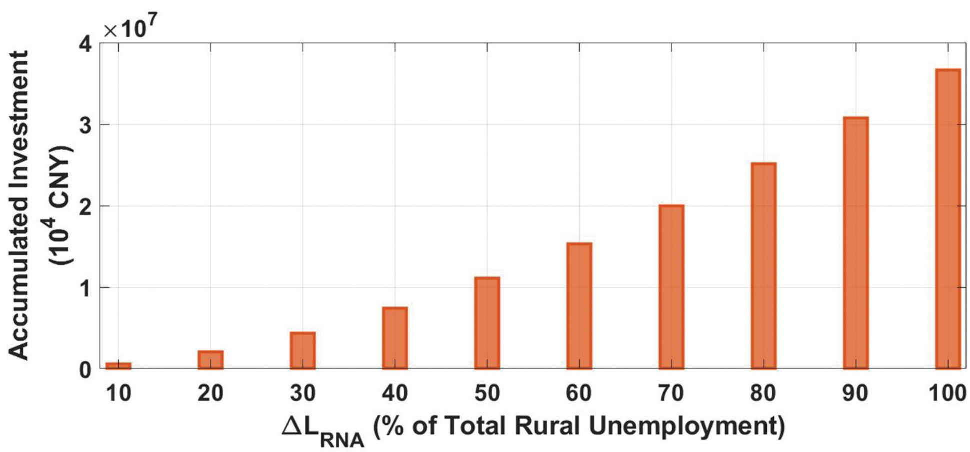

Figure 8. Accumulated investment required, over the period 1985–2013, to absorb varying percentages of rural unemployed in the rural non-agricultural sector.

province. This meant that rural to urban migration can partly be mitigated by making agriculture more climate resilient, not necessarily through innovation in water technology but by diversifying income generating opportunities for the rural poor.

The first scenario analysis simulated government subsidies to energize the rural non-agricultural sector. It showed that if the policy was implemented beginning 1992, the first year of a prolonged drought, the employment in rural non-agricultural sector could increase by up to 16.70% in 1992, and the unemployment rate in rural areas could reduce by 12.82% with more positive impacts on employment in the subsequent years. Such a scenario is similar to quantitative easing implemented by central banks of many countries to keep economies afloat during period of recession (Eichengreen and Rose 1998, Tansey *et al.* 2013). As a result, rural–urban net migration can be curbed by 13.62% over the period 1994–2015. Government has a policy window of 2–4 years after a shock in rural employment to implement policy initiatives that put alternative employment opportunities in place and curb emptying out of rural areas.

The second scenario analysis aimed at investing in rural education to improve the education level in rural residents so that 10%–100% of total rural unemployed could be employed in rural non-agricultural sectors. It showed that in order to effectively increase the amount of skilled labour that are competitively employed in the rural non-agricultural sector, for each year an average investment of between 0.46 to 30.55 billion CNY (with base year 2010) will be required. The investment in education could be sourced from manufacturers and the government. Such programs are currently ongoing in countries such as China and India (Fan *et al.* 2008, Huang 2009, Sun *et al.* 2014).

The paper provided two possible ways that policy makers may intervene to ameliorate rural–urban migration. Even though at high level, the paper provides a first-order assessment of how rural–urban migration can be mitigated and the magnitude of investment that is needed. Such interventions require investments that are merely fraction of regional production (less than 1%) and therefore are financially affordable. Furthermore, the discussed interventions are based on market principles and therefore in interest of regional economy. This shows that there is a tremendous scope for win-win situations in global efforts to tackle regional rural–urban migration phenomenon.

Disclosure statement

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